Body and Void and Newton's De Mundi Systemate: Some New Sources

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Omnis ut est igitur per se natura duabus constitit in rebus: nam corpora sunt et inane.
Lucretius Book I

Introduction

The manuscripts in the Portsmouth collection amply testify to the fact that NEWTON from 1686 to the end of his life in 1727 was concerned to strengthen the basic principles of his Natural Philosophy. As is well known both the *Principia* and the *Opticks* went through three editions during this period: each successive edition containing more reflections on many of the leading philosophical and theologicial questions of the time. Still, many of NEWTON's speculations never reached the press and have remained in manuscript to be analysed and related to the published material. Some of these documents have been ably discussed by Professors COHEN & KOYRÉ.[1] They have convincingly established that NEWTON was actively involved, behind the scenes, in the LEIBNIZ-CLARKE controversy, and that he also produced many private arguments to rebut the leading Leibnizian charges against his philosophy as developed in the *Opticks* and the *Principia*.

The documents to be presented show, it will be argued, that Leibnizian criticism also caused NEWTON to contemplate substantial and extensive changes in the introductory section to Book III of the *Principia*. Some of these were to take the form of definitions and discussions of the notions of void space and sensible matter, which together embody a doctrine fundamental to NEWTON's natural philosophy, and which were intended to be incorporated into the Third Edition. In other documents he was chiefly concerned to clarify the term 'phenomenon'.[2] The main purpose of this article is to put these documents, with a complete analysis, into the public domain. However, Sections VI and VII will be concerned with the nature of the doctrine of the void, as formulated and defended in these definitions, in relation to some of the deeper assumptions of NEWTON's philosophy of nature.

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[1] ALEXANDRE KOYRÉ & I. BERNARD COHEN, "Newton and the Leibniz-Clarke Correspondence", *Arch. Inter. d'Hist. des Sc. Quinzieme Annee*, Nos. 58—59. 1962, pp. 63—126.

[2] These are to be found in ULC. Add. 3965 in sections 13 and 17. Explicit details are given below in conjunction with the manuscripts. It will be shown in section VI that these definitions are essentially connected with the Fourth Rule, and the suppressed Fifth Rule of reasoning in Philosophy, found in this section.

I

Since the definitions contained in these documents were intended to be prefatory to Book III I shall, in this section, discuss the main features of the doctrine of void space as developed in the *Principia* and the *Opticks*, taking note of any substantial changes in successive editions. This will serve to present a body of doctrine which, from 1715, LEIBNIZ began to attack, and which NEWTON contemplated defending in the form of definitions.

These remarks to Book III begin with a plain reference to the vacuum. Referring to the mathematical principles developed in the First Book NEWTON says: —

> These principles are the laws and conditions of certain motions and powers or forces, which chiefly have respect to philosophy; but, lest they should have appeared of themselves dry and barren, I have illustrated them here and there with some philosophical scholiums, giving an account of such things as are of more general nature, and which philosophy seems chiefly to be founded on; such as the density and resistance of bodies, space void of all bodies, and the motion of light and sounds. It remains that, from the same principles, I now demonstrate the frame of the System of the World. [3]

NEWTON intends, then, to demonstrate the structure of the world using mathematical principles. The demonstrations may be mathematical, but the cardinal ideas are indeed physical ones, 'which philosophy seems chiefly to be founded on'. Thus the conceptual structure of this Book is concerned with the visible world of gross bodies; and the central conception is the mutual interaction of these in an unresisting void. As we shall see the composition of the sub-sensible world is also held to be characterised by these antithetical notions.

The doctrine of the void is mainly discussed and defended in Propositions VI and X. Proposition VI which states —

> That all bodies gravitate towards every planet; and that the weight of bodies towards any one planet at equal distances from the centre of the planet, are proportional to the quantities of matter which they severally contained —[4]

is discussed extensively by NEWTON. In the body of his remarks to this proposition he shows, by reference to Corollaries I and II of Proposition XXIV of Book II, where the theory of pendulous oscillations in a vacuum is developed, that "all sorts of heavy bodies descend to the earth from equal heights and at equal times".[5] NEWTON goes on to state that he tried the experiments with "gold, silver, lead, glass, sand, common salt, wood, water, and wheat" and concluded that: —

> ... the quantity of matter in gold was to the quantity of matter in wood as the action of the motive force upon all the gold to the action of the same upon the wood: that is, as the weight of one to the weight of the other; and the like happened in other bodies.

He then proceeds to show, by an imaginative use of analogical reasoning that "the nature of gravity towards the planets is the same as towards the earth".

Although the body of this proposition is based on the experimental evidence for the vacuum, the corollaries are directly concerned with the doctrine itself. In the First Edition, Proposition VI has four corollaries; in the Second and

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[3] ISAAC NEWTON, *Mathematical Principles of Natural Philosophy*. Edited by F. CAJORI, Berkeley, California, 1960 p. 397.

[4] *Ibid.* Book III. pp. 411—414.

[5] *Ibid.* Book III. p. 411.

Third another is added. In all three Editions Corollary III is concerned with the interstitial vacuum[6] in sensible matter. In the First Edition it reads:

> Therefore a vacuum is necessarily granted. For if all spaces were full, the specific gravity of the fluid which fills the region of the air on account of the extreme density of the matter, would fall nothing short of the specific gravity of quicksilver or gold or any other of the most dense bodies. And on that account neither gold, nor any other body, could descend in air; for bodies do not descend in fluids, unless they are specifically heavier than the fluids.[7]

Now in the Second Edition, after an exchange of six letters with COTES which implicitly criticised the formulation of his theory of the void,[8] NEWTON changed the first sentence to read "All spaces are not equally full", adding the following sentence at the end "but if the quantity of matter in a given space, can, by any rarefaction, be diminished, what should hinder a diminuition to infinity?".[9] And in order to clarify this, a further corollary numbered IV was added: —

> If all the solid particles of all bodies are of the same density, and cannot be rarefied without pores then a vacuum is granted. By bodies of the same density, I mean those whose inertia are as their bulks.

Taken together these corollaries are concerned with three distinct but related doctrines. The first is to be found in Corollary III. The argument is not as clearly expressed as it might have been, and the passage would seem to support two alternative interpretations. In the first place, it can be taken to argue from the hypothetical assumption that all spaces whatsoever are entirely filled with a fluid, such that the world becomes an absolute plenum. Then, any given body would be as dense as any other and "the fluid which fills the region of the air" would be equally dense. Thus, since everything would have the same specific gravity, or since the notion of specific gravity would have no application in such a world, it would be impossible for bodies to move: this is patently contrary

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[6] In the sense that the Corollary is primarily concerned with the specific gravity of bodies, which for NEWTON presupposes pores in their composition.

[7] *Principia*. London, 1687, Book III, p. 411.

[8] J. EDLESTON, *Correspondence of Sir Isaac Newton and Professor Cotes*, London, 1850, pp. 65—80. COTES' criticisms and NEWTON'S replies are contained in a series of important exchanges from February to March 1711—12. His main concern is with the Newtonian definition of inertia. He argues that NEWTON has not shown in Corollary III, either *a priori* or experimentally, that two bodies which occupy equal volumes, and are entirely filled with matter, necessarily have the same density or inertia. That this is a necessary consequence, is implied in the Corollary as formulated in the First Edition.

[9] CAJORI, *Mathematical Principles, op. cit.* p. 414. NEWTON is taking the idea of infinite rarefaction seriously; in the limit there is empty space, apart from the entirely dense primordial particles.

Furthermore, NEWTON would seem to have the following argument in mind for the vacuum. All matter from its *vis inertiae*, or resistance to change its place, must give a resistance to motion in proportion to its quantity. And as we find different degrees of resistance to bodies moving in various mediums, there must be different quantities of matter in equal spaces. Consequently there is just so much more of *vacuum*, or absence of matter in one of the spaces, as there is *less* of resistance. When there is no resistance, there will be *no matter:* thus a vacuum.

to experience.[10] The passage cannot be interpreted otherwise. For if, in the second place, it is taken to mean[11] that only the spaces external to bodies are entirely filled, these themselves having void interstices, the argument fails to make sense. According to this interpretation the phrase "would fall nothing short of the specifick gravity of Quick-Silver" would imply that the fluid filling external places would be as dense as dense bodies; whereas, it must be denser. On the first interpretation the phrase makes a minimal reference to the assumption that everything is equally dense, which is not only contrary to experience of dense bodies, but is also inconsistent with the doctrine which NEWTON holds to explain their nature, namely, that difference in density is a result of the comparative ratio between bodies of pores to solid parts. On the second interpretation the phrase would make non-sense of the doctrine itself; for, given that bodies have interstices the fluid external to them, being destitute of pores, could not be as dense as they without bankrupting the explanation of relative densities embodied in the doctrine.

That the first reading is correct can be seen from two passages in the *Opticks*. In Query 22 of the 1717 edition NEWTON, arguing against an aethereal fluid of a Cartesian or Leibnizian sort in favour of an aethereal medium, says: —

> May not Planets and Comets, and all gross Bodies, perform their Motions more freely, and with less resistance in this Aethereal Medium than in any Fluid, which fills all Space adequately without leaving any Pores, and by consequence is much denser than Quick-Silver or Gold?[12]

And in Query 28 where the argument is, in part, concerned to show that resistance is primarily a function of the inertia of the parts of a fluid, he says of the heavens:

> If as dense as Quick-Silver, they would not have much less Resistance than Quick-Silver; if absolutely dense, or full of Matter without any *Vacuum*, let the matter be never so subtile and fluid, they would have a greater resistance than Quick-Silver.[13]

Thus we have the contention that any matter whatsoever, devoid of pores, is entirely dense or in the words of WHISTON, "the greatest that can be, and the most perfect and absolute, or rather infinite".[14] This provides a basis for a hierarchy of relative densities of different sorts of matter, such as gold and quicksilver, and including the aethereal medium of the last two editions of the *Opticks* in so far as it contains particles of matter.

The second doctrine of the Corollaries of Proposition VI is that the quantity of matter in the world is far less than that usually taken to be the case. This would

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[10] Essentially the same argument, often similarly expressed, is to be found in the writings of the Newtonians. For example: J. KEILL, *An Introduction to Natural Philosophy*, London, 1745 (translated from the last Latin Edition). These lectures were given in 1700, Lecture X, p. 117. W. WHISTON, *Sir Isaac Newton's Mathematick Philosophy*, London, 1716. Lecture XXXIV, April 26, 1708, p. 340. R. BENTLEY, *Confutation of Atheism* reprinted in *Isaac Newton's Papers and Letters on Natural Philosophy*, ed. I. BERNARD COHEN, Cambridge, 1958, p. 321. And S. CLARKE's note on p. 96 of *Rohault's System of Natural Philosophy*, vol. II, London, 1728.

[11] Because of the reference to the "region of the air" which tends to give the impression that NEWTON is speaking of external spaces.

[12] ISAAC NEWTON, *Opticks*, New York, 1952, p. 352.

[13] *Ibid*, p. 368.

[14] *Vide*, note 10, item WHISTON, p. 341.

seem to be the import of the passage added to the end of Corollary III, as a result of the criticism of COTES. This very view was expressed much earlier by NEWTON in a document which, as the HALLS indicate, was probably intended to follow this corollary.[15] And it would seem likely that NEWTON had this in mind when he made the change under discussion. It can definitely be assigned to the period of the early 1690's. The document forms part of an elaborate, but unimplemented, revision of the first edition of the *Principia* undertaken in the same period. There exists one earlier draft variant in the Portsmouth Collection, as well as five other sheets containing closely related material.[16] There is not space in this article to discuss these. But they clearly indicate that the corollaries to Proposition VI were intended to have been greater in number and rather different in content from any of the printed versions.[17] They also indicate that NEWTON was concerned, not many years after the publication of the *Principia*, to work out the full implications of this doctrine.[18]

In the document published by the HALLS NEWTON argues, on the basis of the motions of the planets and comets, that celestial space contains very little matter and "That bodies are more rare by far than is usually believed". This conclusion is supported, for example, in a number of ways: the comparative specific gravity of various sorts of heavy bodies, the fact that liquids, even very dense ones such as Quick-Silver, permeate the densest bodies, and that magnetic effluvia readily propagate through them. NEWTON then concludes: —

> One must have recourse to a certain wonderful and exceedingly artificial texture of the particles of bodies by which all bodies, like networks, allow magnetic effluvia and rays of light to pass through them in all directions and offer them a very free passage: and by such an hypothesis the rarity of bodies may be increased at will.

This view of the nature of matter is strikingly similar to that propounded by FATIO DE DUILLIER. Indeed, NEWTON mentions his "mechanical" explanation

[15] A. RUPERT HALL & MARIE BOAS HALL, *Unpublished Scientific Papers of Isaac Newton*, Cambridge, 1962, p. 312.

[16] The earlier variant of the manuscript published by the HALLS is to be found in ULC. Add. 3965. 6. F. 266^{v}. The published variant is in Add. 4005, Fols. 28—9. The five related sheets, which are really alternate versions of the Corollaries of Proposition VI, are to be found in Add. 3965. 6. Fols. 311^{r-v} and 310^{r-v}.

[17] For instance, in Add. 3965. 6. F. 266^{v}, we find the following intended corollaries. "Corollary 4. Without atoms gravity cannot be explained mechanically. Corollary 5. Without void gravity cannot mechanically be explained. Corollary 6. Void is granted. Corollary 7. Bodies are far rarer than is commonly believed. Corollary 8. Atoms are granted. Corollary 9. Granted is an infinite and omnipresent spirit, in which matter is set in motion according to mathematical laws." Also in Add. 3965.6. F. 267^{r}, NEWTON postulated, as an alternative to the void as a condition of mechanically explaining gravity, a hypothesis involving non-gravitational particles. He says "... and the other kind of less dense particles which have to be the cause of the gravity of the denser ones but themselves have no gravity, lest their gravity might have to be explained by a third kind, and that again by a fourth and so on to infinity". NEWTON then attempts to secure acceptance of a vacuum as a means of mechanically explaining gravity by indicating the absurdity in the notion of non-gravitational matter.

[18] He also intended in this unimplemented edition to support Propositions IV to IX of the Third Book by references to the opinion of the ancients regarding gravity, the void and motion. Proposition VI was to have been supplemented by a scholium containing four quotations from Books I and II of LUCRETIUS' *De Rerum Natura* regarding matter and void.

of gravity, since it too must be founded on the existence of void space.[19] Although NEWTON'S ideas on matter and void as expressed in this document were not available to LEIBNIZ, those of a similar type were to be found in the 1704 English and 1706 Latin editions of the *Opticks*. For instance the Latin edition, which he certainly read, says of the texture of bodies in Proposition VIII, Book II, Part III: "Atq; hinc quidem id insuper intelligi potest; Corpora multo esse rariora, multoq; plures intra se Meatus habere, quam vulgo existimatur".[20] The supporting arguments are also the same as those of the document.

The third doctrine of the Corollaries to Proposition VI, Book III, asserts that the "Primigenial" particles are of the same density. NEWTON cannot be taken to include the ultimate particles, when he speculates that "a dimunition (of matter) to infinity" may be possible. Rarefaction and condensation can only be explained, in his view, by supposing that forces operate on these particles causing them to recede from or to approach one another; and hence diminishing or increasing their numbers, and the resulting agglomerations, which have interstices, present in any given void space. As Corollary IV states, the lack of pores in the ultimate particles demands that a vacuum must be granted so as to account for such phenomena. Thus, it is the quantity of sensible and sub-sensible matter that may be diminished, not the ultimate particles which "are of the same density". The definition of inertia embodied in the corollary is the same as that to be found in Definition XV of *De Gravitatione*. There NEWTON says: — "Bodies are denser when their inertia is more intense, and rarer when it is more remiss".[21] Accordingly, from about 1670 inertia becomes the primitive concept in terms of which density and quantity of matter are to be explicated,[22] and in modern terminology NEWTON believes that the ratio of inertia to bulk is a constant for all "elementary" particles.

The debate over the vacuum was not restricted to the interstitial vacuum. LEIBNIZ also took issue with NEWTON'S assertion of the vacuity of celestial space. NEWTON'S published statements on this are not univocal. These will be examined and the apparent discrepancies explained, in general, by chronology

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[19] *Cf.* BERNARD GAGNEBIN, "De la Cause de la Pesanteur. Memoire de Nicolas Fatio de Duillier Presenté à la Royal Society le 26 Fevrier 1690", *Notes and Records of the Royal Society*, 6, 1949, p. 117. FATIO says: "Je suppose que les diferens Epaces du Monde sont presque entierement vuides de Matiere. Plusieurs Phenomenes que nous observons dans la Nature, etablissent cette extreme Rarété des Corps. Elle est necessaire, dans mon Hypothese, afin que les Particules de la Matiere, qui cause la Pesanteur, aient leurs Mouvemens, en Lignes droites, extrement Libres." p. 127.

[20] ISAAC NEWTON, *OPTICE sive de Reflexionibus, Refractionibus, Inflexionibus Coloribus LUCIS*, London, 1706, p. 229. There is no substantial difference in the English and Latin editions. In a letter to LEIBNIZ in 1694. FATIO states that NEWTON believes there is much more 'de vuide que de plein'. However, no arguments are given. *The Correspondence of Isaac Newton*, Vol. III, p. 308.

[21] HALL & HALL, *op. cit.* p. 115.

[22] Density is put proportional to inertia when volume is constant. It is interesting to note that inertia is an intensive quality rather than an extensive one. However, in so far as NEWTON asserts that the proportionality of matter to weight is proved experimentally (Def. 1 of the *Principia*), his definition of mass is circular since this involves density being proportional to gravity of matter and volume conjointly.

and shift of reference. Proposition X Book III of the Principia is straight-forward, stating:

That the motion of the planets in the heavens can be conserved for an exceedingly long time.[23]

The remarks are plainly concerned to show that celestial spaces are void of sensible matter. We find in the Third Edition a paragraph added which appeared in neither of the two earlier editions. Making use of the mathematical machinery of the Scholium to Proposition XXII of Book II, NEWTON argues that the air two hundred miles above the earth is very rare in comparison with that near the surface. He then says:

In the spaces near the earth the resistance is produced only by the air, exhalations and vapours. When these are carefully exhausted by the air pump from under the receiver heavy bodies fall within the receiver with perfect freedom and without the least sensible resistance. And therefore the celestial regions being perfectly void of air and exhalations, the planets and comets meeting no sensible resistance in those spaces will continue their motions for a very great length of time (diutissime movebuntur).[24]

Essentially the same argument is to be found in Query 20 of the Latin edition of the *Opticks* and in the 1717 English edition. In the English edition it is as follows:

Now if the Resistance in a Vessel well emptied of Air, was but a hundred times less than in the open Air, it would be about a million of times less than in Quick-Silver. But it seems to be much less in such a Vessel, and still much less in the Heavens, at the height of three or four hundred miles from the Earth, or above. For Mr. *Boyle* has shew'd that Air may be rarified above ten thousand times in Vessels of Glass; and the Heavens are much emptier of Air than any Vacuum we can make below.[25]

NEWTON then computes the rarity of the air up to a height of 228 miles above the earth from the relation of its density to the atmospheric force compressing it. Notice that he claims in the passage from the *Principia* that the celestial regions are "perfectly void of air and exhalations", and in the Query that regions without atmosphere are possible. This seems to imply that the extreme outer regions are very probably absolutely void. However, already in the Second Edition of 1713 NEWTON had begun to put some matter into space. Reference is made to Proposition XL of Book II at the beginning of the basic Proposition X of the Third Edition. There, in an addition to a long Scholium, made in the Second Edition and repeated in the Third, we find: —

And therefore the celestial spaces, through which the globes of the planets and comets are continually passing towards all parts, with the utmost freedom, and without the least sensible diminuition of their motions must be utterly void of any corporeal fluid, excepting perhaps, some extremely rare vapours and the rays of light.[26]

Also in Query 28 of the 1717 Edition of the *Opticks* we find: —

And therefore to make way for the regular and lasting Motions of the Planets and Comets, it is necessary to empty the Heavens of all Matter, except perhaps some thin Vapours, Steams, or Effluvia, arising from the Atmospheres of the Earth, Planets, and Comets, and from such an exceedingly rare Aethereal Medium as we described above.[27]

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[23] CAJORI, *Op. cit.* Bk. III, p. 418.
[24] *Ibid.* Bk. III, p. 419.
[25] *Opticks, op. cit.* Query 28, p. 367.
[26] CAJORI, *Op. cit.* Bk. II, p. 366.
[27] *Opticks,* Op. cit. Query 28, p. 368.

Thus we have an apparent incompatibility between the perfect celestial vacuum of the addition to Proposition X in the Third Edition of the *Principia* and of the first passage cited from Query 28, and the imperfect vacuum of Proposition XL and of Query 28 with respect to the second quotation from it. There is the further difficulty that the addition to Proposition X concerning the perfect vacuum occurs some time after NEWTON had begun to entertain the possibility of an aethereal medium of differential density in celestial spaces.

These questions are best answered if we first consider, in general outline, the development of NEWTON'S thought on the void and the aether in the early years of the Eighteenth Century. There is no decisive evidence to indicate whether or not he accepted some sort of aethereal hypotheses in the period from 1692 to 1713. In this period he seems to have seen the world as being comprised of matter and void, the former depending for its existence and motion on the ultimate efficacy of God's Will. In the years prior to the republishing of the *Opticks* in English,[28] he began again to consider a "mechanical" aether: hence, the Queries of the 1706 edition had to be changed, in part, to accommodate this development in his thought. Accordingly Query 20 of that edition was enriched with a mention of "such an exceedingly rare Aethereal Medium ...". And if spaces can contain a "rare" Aethereal Medium, it is not surprising that they should also contain vapours and exhalations.

The restriction of "vapours and exhalations" to the *solar* system can finally remove the apparent incompatibility. NEWTON is not clear in his use of the term *celestial*, applying it indifferently to regions within and without the solar system. From the passage quoted from Query 28 it is clear that he is supposing the existence of vapours, exhalations and effluvia, in the atmosphere of the *Solar system*, 'arising from ... the Earth, Planets, and Comets'. Thus, since Proposition X and the first quotation from Query 28 state that the farther above the earth the rarer becomes the amount of matter, by implication, eventually regions far beyond it and entirely void will be reached.[29] So it seems that only the spaces of the solar system contain some matter. And the aethereal medium being 'elastick', very 'rare' and presumably diffusible, by virtue of its very 'subtile' particles, through the great distances of this inner system is supposed by NEWTON to be of little hindrance to the passage of dense bodies. Only fluid media of the Leibnizian variety would produce such an effect. Still, as I shall show, the Newtonian Aethereal Medium *is* incompatible with the possibility of a perfect vacuum in the outer celestial regions, and involves other difficulties as well.

Thus it is clear that in both the *Principia* and the *Opticks* NEWTON accepts the interstitial and celestial vacuum. Acceptance of this latter doctrine was

[28] HENRY GUERLAC, 'Newton et Epicure', Conférence donnée au Palais de la Découverte, Paris, 1963. Professor GUERLAC has gone some way to establishing this view by a comparative analysis of the difference in the Queries of the 1706 edition from those of the 1717 edition. There is much manuscript evidence from the period under discussion to support this; for instance, *Vide.* note 17, F. 266^{v}.

[29] BENTLEY, using the same argument, is quite explicit. "And yet the higher you ascend above that region (Orb of Saturn), the Rarefaction still gradually increases without stop or limit: so that, in a word, the whole Concave of the Firmament, except the Sun and Planets and their Atmospheres, may be considered as a mere Void." *Vide.* Note 10, item *Papers and Letters*, p. 325.

restricted to NEWTON and his immediate circle of disciples. Even HUYGENS, an adherent of the atomic philosophy, did not postulate a *Vacuum Separatum.* Criticising NEWTON's aether for not being able in his terms to account for the action of gravity or of light he says in the *Addition* to the 1690 edition of the *Discours de la Cause de la Pesanteur:*

Pour examiner donc ce point, je dis que la matiere etherée peut etre censée rare de deux manieres, sçavoir ou que ses particles soient distantes entre elles, avec beaucoup de vuide entre deux; ou qu'elles se touchent, mais que le tissu de chacune soit rare, & entre-meslé de beaucoup de petits espaces vuides. Pour ce qui est du vuide, je l'admets sans difficulté, & meme je le crois necessaire pour le mouvement des petits corpuscules entre eux. N'estant point du sentiment de Mr. Des Cartes, qui veut que la seule étendue fasse l'essence du corps; mais y adjoutant encore la dureté parfaite, qui le rende impenetrable, & incapable d'estre rompu ni écorné. Cependant à confiderer la rareté de la premiere, je ne vois pas comment alors on pourroit rendre raison de la Pesanteur: & quant à la Lumiere, il me semble entierement impossible, avec de tels vuides, d'expliquer sa prodigieuse vitesse, ... C'est pourquoy je tiens qu'une telle rareté ne sçauroit convenir aux espaces celestes.[30]

Thus only the existence of tiny interstices within sensible bodies is acceptable to HUYGENS.

II

The various facets of NEWTON's doctrine of the void as expressed in his major published writings have been discussed. It remains to consider the nature of LEIBNIZ's opposition to this doctrine as developed in the controversy with CLARKE.

As early as 1689 in the *Tentamen de Motuum Celestium Causis*[31] LEIBNIZ implicitly attacked the void. Probably provoked by the sustained attack against the vortex theory in Book II of the *Principia*[32], he attempted to show that Keplerian concepts are applicable in a world full of matter. Thus, the *Tentamen* can be seen as an attempt to sustain the plenum against void spaces. From 1710 his general criticisms of NEWTON's natural philosophy, as shown in the *Théodicée,* become explicit. Still, at this stage there is no definite attack on the vacuum as such. The first public attacks on the doctrine occur in an exchange of three letters between N. HARTSOEKER and LEIBNIZ in the *Memoires de Trevoux* for February 1711, and in a letter published by P. RÉMOND in August 1713.[33] Sustained criticism, however, only begins in the *Leibniz-Clarke Correspondence,*[34]

[30] *Oeuvres completes,* The Hague, Vol. XXI, p. 473.

[31] J. GERHARDT, ed., *Leibnizens Mathematische Schriften,* Halle, 1860 VI, p. 144 sq. 161 sq. Originally in *Acta Eruditorum* 1689. 81—96.

[32] It is not certain that LEIBNIZ had read the *Principia* prior to composing his *Tentamen.* He himself tells us that he had only read an account of the *Principia* in the *Acta Eruditorum* for June 1688, pp. 304—315. *Vide* C. I. GERHARDT. *Leibnizens Mathematische Schriften,* Halle, 1859, IV, pp. 87ff. Also HUYGENS remarks in a letter to LEIBNIZ on 8 February 1690: "You have only seen an extract of his book and not the book itself." *Oeuvres Completes,* IX p. 367.

[33] These three letters form only a part of the correspondence which began in 1706. The void is criticised implicitly by LEIBNIZ. The letters were republished in the *Memoires of Literature* in 1712 and COTES drew NEWTON's attention to them. *Vide.* Note 8, p. 158. RÉMOND's criticisms will be discussed below.

[34] Throughout, references and quotations are from ROBINET's edition of the Correspondence, unless otherwise indicated. A. ROBINET, "Correspondence Leibniz-Clarke", Paris, 1957.

and falls into three categories. In the first place there are arguments of a theological nature based on the "principle of the best". Those of a philosophical character are based on the principle of sufficient reason, and the view that void space constitutes, if it exists, an attribute without a subject. LEIBNIZ also holds, in general, that the atomic philosophy embodies a shallow and incomplete metaphysics. Lastly, there are arguments of a "quasi-experimental" nature such as the view that there is matter void of heaviness and that viscosity is the important factor in the resistance of fluids.

It is only in his second letter to CLARKE towards the end of November 1715 that LEIBNIZ launches his first attack on the vacuum. It is here that he introduces the principle of sufficient reason, the implications of which had been fully discussed earlier in the *Théodicée*.[35] LEIBNIZ claims that from this principle (together with the principle of contradiction) the whole of theology and natural philosophy can be justified. The following passage plainly shows that he interprets the Newtonian doctrine as holding that the world contains a great paucity of matter: —

... LA MATIERE EST LA PARTIE LA MOINS CONSIDERABLE DE L'UNIVERS: c'est qu'il admet outre la Matiere, un espace vuide, et que selon luy la matiere n'occupe qu'une trés petite partie de l'espace. Mais Democrite et Epicure ont soutenu la même chose, excepté qu'ils differoient en cela de M. Newton du plus au moins; et que peut étre selon eux, il y avoit plus de matiere dans le monde, que selon M. Newton. En quoy je crois qu'ils étoient preferables; car plus il y a de la matiere, plus y-a-t-il de l'occasion à Dieu d'exercer sa sagesse et sa puissance.[36]

The argument is strictly a theological one, grounded on the principle of "la perfection de Dieu", and not on the principle of sufficient reason if that is taken to mean that God must always have a motive for acting in one way rather than in another. For the objection to the vacuum is couched in terms of God's wisdom and power; if there is a vacuum in nature there is less matter and less reality, and hence there is a limitation in God's power of creation and this in turn constitutes a violation of his infinite perfection.

In his second reply of December 1715 CLARKE rebutted this by pointing out that:

How small soever the QUANTITY of matter be, God has not at all the LESS SUBJECT to exercise his WISDOM and POWER upon: For, Other things, as well as MATTER, are equally subjects on which God exercises his POWER & WISDOM.[37]

LEIBNIZ in his next letter of the 25th February 1716 simply denies that there are things other than matter on which God can exercise his power; "car je tiens que toute substance cree est accompagnée de matiere".[38] On the 15th May CLARKE replies that the "determinate quantity of matter" now in the world was the "most convenient" for the "present state of things".[39] To this LEIBNIZ replies that there is no possible reason to limit the quantity of matter for "il faudra tousjours y adjouter quelque chose, pour agir suivant le principe de la perfection

[35] Ed. J. E. ERDMANN, *Opera Philosophica, pars prior*. Berlin, 1840, Preface, pp. 468—479.
[36] ROBINET, *Op. cit.* p. 36.
[37] *Ibid.* p. 48.
[38] *Ibid.* p. 55.
[39] *Ibid.* p. 70.

des operations Divines".[40] Thus the present constitution of things cannot be the best possible. Now in his fourth reply of the 26th June, CLARKE changed the character of the exchange on the vacuum by introducing experimental evidence. This was probably in response to a letter which LEIBNIZ sent to CAROLINE on June 2nd and in which he says: —

Je ne crois pas qu'il ya ait aucun espace sans matiere exclus des experiences qu'on appelle du vuide, n'excluant qu'une matiere grossiere qu'on tire de la cavité du cerre par le poids du vif argent avec Torricelli, et par la pompe avec M. Guerike. Car les rayons de la lumiere, qui ne sont point sans quaelque matiere subtile passent à travers de verre.[41]

CLARKE points out that though rays of light and other matter in small quantities may be in a receiver, "the WANT of RESISTANCE plainly shows that the GREATEST PART of THAT SPACE is void of MATTER. For SUBTLENESS or FINENESS of MATTER, cannot be the cause of WANT of RESISTANCE".[42] He also argues that quicksilver is as subtle as water but yet makes "more than ten times the resistance". Therefore resistance arises from the quantity of matter not its grossness.

LEIBNIZ's reply to this, on August 18th, attempts to argue that in the exhausted receiver there are beams of light, magnetic effluvia and other matter "non pesante et qui ne resiste point sensiblement".[43] To this CLARKE replies on October 29th that the notion of matter void of gravity is absurd and that resistance is proportional to the quantity of matter or inertia. To LEIBNIZ's claim that it is not the density of matter but the difficulty of "giving place" of the liquid which causes resistance to moving bodies, CLARKE replies that with such fluids as water and quicksilver (the resistance of which is in question) there is little tenacity, and hence the only important factor is their quantity of matter.[44]

The exchange concerning the void ends with CLARKE's defence in October 1716. In his edition of this *Correspondence* published in 1717,[45] he added as an appendix to LEIBNIZ's fourth paper a postscript to a letter which LEIBNIZ had written to CAROLINE on the 12th May 1716. It is almost entirely devoted to repudiating the vacuum. LEIBNIZ begins by saying: —

Tous ceux qui sont pour le Vuide, se laissent plus mener par l'imagination que par la raison. Quand j'étois jeune garçon, je donnay aussi dans le vuide et dans les Atomes; ⟨mais la raison me ramena⟩.[46]

[40] *Ibid.* p. 91 29th May 1716. It is in this letter that LEIBNIZ makes the charge that void space is an attribute without support: "Si l'espace est un realité absolue bien loin d'etre une proprieté ou accidentalité opposée á la substance, il sera plus subsistant que les substances." CLARKE replies in Fourth Letter "Void Space is not an *Attribute without a subject;* because by *void space,* we never mean *Space void of everything,* but void of Body only." *Vide.* Note 1, KOYRE & COHEN p. 90—91, where there is a discussion of this point.

[41] *Ibid.* p. 78.

[42] *Ibid.* p. 109. CLARKE also stresses in this passage that "EXTRA-MUNDANE SPACE, (if the Material World be Finite in Dimensions), is not IMAGINARY, but REAL."

[43] *Ibid.* p. 138.

[44] Ibid. p. 192. Also see *Opticks,* Query 28 p. 365, the Scholium to Proposition XIX, Bk. II of the *Principia,* and Cotes' Preface to the Second Edition.

[45] *A collection of papers which passed between the late learned Mr. Leibnitz and Dr. Clarke, in the years 1715 and 1716. Relating to the principles of natural philosophy and religion,* London, 1717.

[46] ROBINET, *Op. cit.* p. 76.

He then argues that to admit the vacuum "c'est attributer a Dieu une Production tres imparfaite", pointing out that as a principle every perfection that God could create in the natural order, "sans deroger aux autres imperfections", has been created. "Or figurons-nous un Espace vuide, Dieu y pouvoit mettre quelque matiere sans deroger en rien à toutes les autre choses. Donc il l'y a mise. Donc il n'y a point de d'Espace entierement vuide: Donc tout est plein". Moreover, he claims that the same argument can prove that there are no atoms. LEIBNIZ next outlines a specific argument against the void based on the principle of sufficient reason and the notion that matter is more perfect than the void; namely, that if there were a vacuum there would not be a sufficient reason for determining the proportion of matter to void space; space being homogeneous, why should God create matter here rather than there?

Such, then, are the Leibnizian objections to the vacuum. It might be thought that he is entirely misguided in attempting to confute a purely empirical statement — the existence of a vacuum — with predominantly a priori statements about the world being a plenum. Yet, as will become clear, he had some justification for regarding the Newtonian expression of the atomic theory as a metaphysical system. And it is clear that NEWTON did so as well. For, as we shall see, he recognised an irreducibly metaphysical substratum supporting his world-view at its deepest level. This he chose to minimise, mainly for polemical reasons, in the Definitions to be discussed.

III

The Definitions will now be given in the order in which they were probably written. In the Appendix the Latin transcriptions will be found. These successive draft variants show clearly the development of NEWTON's ideas. They also indicate that he debated the manner and form of their presentation. His practice of using square brackets to mark off material to be omitted when the document would be copied will be followed; angle brackets will be employed to indicate my additions, interpolations or glosses to the text in the interest of clarity; and finally words or phrases scored out or interlineated by NEWTON will be italicised.

Draft No. 1 (1 p. Fol. 641r). ULC. Add. 3965. 17.[47]

Judging from its lack of organisation and its incompleteness this draft probably represents an early, perhaps the earliest, attempt on the part of NEWTON to formulate his ideas on the notion of void and body. There are no definitions of these terms as there are in later draft variants. It is a catalogue of ideas, developed in a rather random fashion, which is given shape in the later documents. The page is heavily scored and has many interlineations. It would seem that the material follows on from a separate sheet which is no longer to be found in the manuscript remains.

Mathematical solids are not perceived by touching nor cause a resistance, nor are they usually called bodies ... The Quintessence is different from the four elements and is subject to none of the senses nor can it be numbered among phenomena. Prime

[47] Where ideas are common to the five variants, Footnote remarks will be given in Draft No 3. In some cases I have added punctuation. The latin, however, is presented in the Appendix as it was written. This type of sub-heading will be used for all manuscripts in both the text and the Latin Appendix.

matter which is neither a thing nor possessed of quality nor a thing that can be measured is not a phenomenon. The subtle matter by which the heavens are filled ⟨an unintelligible phrase is interpolated here⟩ is not a phenomenon. And things which are not phenomena, have no place in experimental philosophy. Inductive argument taken from experiments *taken* and the observations of sensible things on which experimental philosophy is based, cannot be applied to hypothetical or metaphysical entities *except by means of hypotheses it ought not to be extended* in as much as they are not phenomena; therefore the things which are said in this book concerning bodies *by the power of induction* bears no reference to entities of this sort. Here we are concerned only with *phenomena* sensible things *and their parts, the other things are more properly treated of in metaphysics and hypothetical philosophy.* ⟨Above this last phrase is written another which is heavily scored out and quite unintelligible.⟩ *Because in these things only the argument of induction has place.* The other things which cannot be perceived, but are termed bodies hypothetically by some people, these things are more properly treated of in metaphysics and hypothetical philosophy. We must begin from phenomena. Experimental philosophy exists in treating of such things. From this philosophy to *efficient and final causes and* to hypothetical philosophy men must proceed. The solid orbs in which the planets inhere *are not phenomena.* The subtle matter in which flow bodies *move without resistance* is not a phenomenon. *And things which are not phenomena* ⟨The rest of the sentence, which is not complete, is too heavily scored out to be intelligible.⟩

And just as geometers define a line as that which has length without breadth so that *their propositions* concerning lines of this sort are in this way understood and *however a line having breadth* in mechanics and other sciences *however* a line *having breadth* has a place: thus body *and vacuum* are here defined [*not in order that we deny that other bodies exist but in order that we may show in what sense these words are to be understood in what follows. The propositions which follow are understood of bodies of this kind. About other bodies let authors in other sciences dispute.*] So that these words may be understood in the sense *defined* in what follows. About other sorts of bodies and other sorts of void let authors in other sciences dispute.

Draft No. 2 (1 p. Fol. 437v) ULC. Add. 3965. 13

In this draft the ideas take on more definite shape. Definitions of the terms body and vacuum are given. The interlineations and phrases struck out indicate that NEWTON'S views are still developing; nor is he sure, yet, of their final order of presentation. Here a list of things is given that are taken to examplify the notion of a body. In the discussion of this term there are to be found some new ideas not in Draft I. The remarks to the definition of vacuum on this sheet are interesting and entirely different from what is to be found in later drafts. The notion of exhalations and vapours is here introduced. The sheet is badly torn in the left-hand bottom corner so that some of the words supplied are necessarily conjectural. These will be indicated in the Latin appendix.

Definition I

Body I call everything tangible in which there is a resistance to tangible things, and whose action *resistance*, if it is great enough, can be perceived.

It is indeed in this sense that the common people always accept the word body. And of this sort are *The Earth, Planets, Comets,* metals, stones, sand, clay, mud, *earth,* salts, wood, bones, flesh, water, oil, milk, blood, air, wind, smoke, exhalations, flames, and whatever can be included under the four elements, and flow from them by exhalations and return to them by condensation: *I add the stars and the heavenly bodies: The Planets and Comets act* ⟨written above this last phrase is the following.⟩ These emit and reflect light and are weighed down by their constituent parts *and are numbered among phenomena and in their motions observe the laws of bodies.* [Mathematical solids are not perceived by touching nor cause a resistance nor are they usually called bodies.]

Vapours and exhalations on account of Their rarity lose almost all perceptible resistance, and in the common acceptance often lose even the name of bodies and are called spirits. And yet they can be called bodies in so far as *they are the effluvia of bodies and* have a resistance proportional to density. [But if the effluvia of bodies were to change thus in respect of their forms so that they were to lose *all* power of resisting, *and cease to be numbered among the phenomena*, these I would no longer call bodies: for I speak with the common people.]

Definition II

Vacuum I call every place in which a body is able to move with resistance.

Thus it is called by the common people. If any man should contend that bodies are given, which by touch are neither felt nor cause a resistance, this man is now disputing the grammatical significance of the word by calling things bodies which are generally not called such by people: and I should prefer to go with the crowd *who at least are capable of giving things names*. Things which by touching press together and by pressing together act on other things, and things which do not press together and, since they do not press together, do not act on other things, thus they can be mutually distinguished: so that they may truly be called bodies;[48] but let these other bodies be called intangible things or things ⟨rest of this phrase is missing⟩ *or insensible matter or* let them be designated by another name, and the common type of body let it rejoice in a third name such as substance, or being, or that which acts, or ⟨rest of this phrase is missing.⟩ Thus that ambiguity of words will be avoided from ⟨a phrase is missing⟩ which ever arguments of ideas are accustomed to arise and since it is disputed about bodies ⟨a phrase is missing⟩ as phenomena but ⟨because of a torn corner the rest of the remarks cannot be made out.⟩

Draft No. 3 (1 p. Fol. 422r) ULC. Add. 3965. 13

On this sheet the definitions of body and vacuum are substantially the same as in Draft 2: however, they are now numbered "*Definito II*" and "*Definito III*". On the verso side of the sheet there is a definition of the term 'phenomenon' marked "*Definitio I*". The significance of this will be discussed later. In the top left-hand corner of the sheet we find written in NEWTON's hand "pag. 359". This is the pagination of the Second Edition of the *Principia*. It is plain then that these definitions were intended to occupy a place in the Third Book just after the *Regulae*, displacing Phenomena I and II to the following page. This draft appears to be a more polished version of Draft I; moreover, some of the ideas are more fully developed. For instance, the comments on the definition of body are more extensive than in either Draft I or 2. For this reason and for the following it is probably a later version. In later drafts the stars, planets and comets no longer appear as examples of material bodies. Again, the sentence "I add the heavenly bodies", and the criteria of materiality *viz.*, bodies emitting and reflecting light, and their parts coming together by the force of gravity, is interlineated in Draft 2 and is not present at all in Draft I. But a more important reason is this. In Draft 1 NEWTON does not wish to deny that there are other sorts of bodies; but he is concerned to indicate the sense that the word will have within the framework of his *Systemate Mundi*. In Draft 2 he develops this notion by attempting to formulate criteria for distinguishing other sorts of bodies from material bodies.

[48] The sentence structure leaves much to be desired. The meaning, however, is clear. NEWTON is indicating a criterion of materiality. Bodies act on one another in virtue of their solid, impenetrable content. Mathematical solids (*viz.* above) cannot act; for they pass through one another. The same criterion is implied in Definition II of Draft No. 3.

Also implicit in Draft 1 is the view that body and void are correlatives, one being tangible and the other not. This view is explicitly developed in Draft 3 and in later draft variants; whereas the criteria for distinguishing types of bodies found in Draft 2 is not. Therefore Draft 3 is probably a later variant than either Draft 1 or 2.

Definition II

Body I call everything which can be moved and touched, in which there is resistance to tangible things, and its resistance, if it is great enough, can be perceived.

It is indeed in this sense that the common people always accept the word body. And of this sort are metals, stones, sand, clay, mud, earth, salts, wood, bones, flesh, water, oil, milk, blood, air, wind, smoke, exhalations, flames, and whatever can be included under the four elements or flow from them by exhalation and return to them by means of condensation.[49] I add the heavenly bodies. These emit and reflect light and are numbered among phenomena, and are weighed down by their parts pressing heavily upon them, and assume a round shape, and in their motions observe the laws of bodies. Vapours and exhalations on account of their rarity lose almost all perceptible resistance and in the common acceptance often lose even the name of bodies and are called spirits. And yet they can be called bodies in so far as they are effluvia of bodies and *have a force* of resistance *have* proportional to their density. Mathematical solids are not *perceived* do not move by touching *nor cause a resistance*, nor are they usually called bodies. [The quintessence is different from the four elements, and is subject[50] to none of the senses nor is it numbered among phenomena.[51] The prime matter which is neither a thing, nor possessed of quality, nor a thing which can be measured, is not a phenomenon. The solid orbits in which the planets inhere are not phenomena. The subtle matter in which the *planets* float, and *in which* bodies move without resistance is not a phenomenon.[52] And what are not phenomena, and subject to none of the

[49] The reference to the four elements is puzzling. It is probably a compressed way of referring to the theory of transmutation which is elaborately developed in the Third Book, CAJORI, Op. cit. pp. 522, 526—530 and p. 542. The passage at p. 542 was only added in the Third Edition. The Comets continually supply a "vapourous spirit" which considerably rarefies and dilates in the heavens. By the power of gravity this vapour is drawn slowly to the earth and, condensing into water, augments the dwindling supply of nourishing fluids necessary to sustain life: whereupon the various transmuting agents produce physical stuffs such as mud, clay, sand etc. In the *Opticks* there are many passages which support a theory of terrestrial transmutation, *i.e.* Query 30, pp. 374—375 and also the Draft *Conclusio* to the *Principia*, HALL & HALL, *Op. cit.* p. 341. In each case the process begins with water. All phenomena, accordingly, arise from and return to this common stuff, which is itself replenished by the "vapours" of the Comets' tails. Thus, the phrase under discussion, coming as it does directly after the list of physical bodies, is a convenient way of referring to the contents of the perceptible world, the theory which explains their transmutations, and the occurrence of such intermediary states as vapours and exhalations. The influence of alchemical theories is beyond the scope of this paper.

[50] NEWTON did not close this bracket. It is clear however that he intended all the material after the bracket to be deleted when the passage would be copied; for this is precisely the material left out when the Definitions became part of a revision sequence. *Vide* Draft No. 5 of Latin appendix.

[51] This would appear to be a reference to the chemical use of the term "Quintessence" in the seventeenth century: that is, something which is approximated to, but never reached in experiment. It is very probable also that the term had alchemical significance for NEWTON.

[52] This is plainly a rejection of the Fluid aether of the Cartesians and the Leibnizians. For instance in one of the variants of the letter sent to LEIBNIZ via CONTI in February 1715/16 NEWTON says of LEIBNIZ: "He pretends that all places not filled with tangible bodies may be filled with intangible corporeal Fluid." KOYRÉ & COHEN, *Op. cit.* p. 109.

senses, have no place in experimental philosophy. Inductive argument taken from experiments and the observations of sensible things on which experimental philosophy is based cannot be applied except by means of hypotheses to hypothetical or metaphysical entities. Therefore, the things which are said in this book about bodies through the power of induction bear no reference to entities of this sort. Here we are concerned only with sensible things and their parts, for it is in these things alone that the inductive argument has its place. The other things which cannot be perceived, but yet are hypothetically termed bodies by some people, these things are more properly treated of in metaphysics and hypothetical philosophy. *We must begin from phenomena* ⟨The following phrase is written above the last.⟩ *Philosophy begins with phenomena.* Experimental philosophy consists is treating of such things. One must pass from *experimental* philosophy to the efficient and final causes *of things* and *from all these to the nature of imperceptible things and finally* to hypothetical philosophy. At the beginning of the first book I have defined the quantity of matter so that it may be treated in mathematical terms; here I have defined body composed of such matter in order that it may be treated in physical terms.

Definition III

Vacuum I call every place in which bodies are able to move without resistance.

It is in this sense that the common people understand the significance of the word. But it follows from the first Definition *that vacuum is that which is not a tangible thing and does not impede the motion of bodies.* For just as geometers define a line that has length without breadth, so that their propositions concerning lines of this sort are only understood, and in mechanics, however, and other sciences the line having breadth has a place; thus body and vacuum are here defined so that these words may be understood in the sense defined in what follows. About other sorts of bodies and other sorts of void let authors in other sciences dispute.

Draft N.4 (1 p. Fol. 430r) ULC. Add. 3965. 13

There is plain indication in this draft that NEWTON considered presenting his views in another form: the sheet is entitled "Scholium" and was intended as a redaction of Page 360 of the Second Edition which contains "*Phaenomena*" III and IV. This material is interesting. For it connects the new ideas intended for Book III with basic concepts, such as inertia and mass, from the First Book. Thus we have in one document a terse philosophical presentation of NEWTON's leading doctrines concerning the nature of bodies in the physical world. This draft was probably written after No. 3. NEWTON has purposely left a space in it for the list of material bodies and the criteria of materiality to be filled in when the document would be copied. The material which follows on after this indication is the same in form and content as the remark supporting the definition of vacuum in Draft 3. It is bracketed and a line drawn through it. This usually meant that such material was not to be incorporated into the final copy. In this case, however, it would seem that NEWTON intended that the material not be suppressed — for it appears in the final draft — but that it should follow on after the next section which summarises the remainder of the remarks on the term body of Draft 3.

Scholium

In the first definition of the first book I *defined I described what is* the quantity of matter in any given body, and said that throughout I understood this quantity by the *name* body or mass, and that in the meanwhile I have no account here of the medium, if there is any such thing, freely pervading the interstices of the parts. And in the third Definition *I said* that the force of inertia was proportional to the body

and was innate and essential, and that this force is the power of resistance by which every body *attempts to stay preserves* in its state of rest, or moving uniformly in a right line. By body I understand everything tangible, in which there is a resistance to bodies touching it, and whose resistance, if it is sufficiently great, can be perceived. For it is in this sense that the common people always understand the word body. And of this type[53] ... *especially because* [and finally we must pass to *philosophy* hypotheses. Therefore I understand the word body *in this proposition* in no other sense than the one which I have defined. And vacuum I call all space which is destitute of bodies of this kind. Just as geometers define a line as that which has length but no breadth, so that their propositions concerning lines of this sort are only understood; and in mechanics, however, and in other sciences, the line has breadth: so body and vacuum are here defined so that they may be understood in the sense defined in *this proposition and in the following of this book.* But let others who, wander beyond the limits of experimental philosophy, *authors in other sciences* discuss other bodies and other sorts of void][54] ⟨there is a large space left in the manuscript here: Newton begins again with a dash⟩ — Because the inductive argument has place in these things alone. Therefore *the things which are here affirmed* by the power of induction about the universal gravity of bodies, *here affirmed* have no bearing on the quintessence, and first matter, and solid orbs, and subtle matter, which are not phenomena. [Here I am speaking of bodies which are *truly touched and* truly have the *power* of inertia and by means of this power truly cause resistance to tangible things.][55] *And these.are not the bodies of which I am speaking here.* These things which are not preceived, but are hypothetically named bodies by some people, must be more properly dealt with in metaphysics and hypothetical philosophy. Philosophy begins with phenomena through the inductive argument. Experimental philosophy consists in dealing with these things. It is necessary to pass from experimental philosophy to the *final and* efficient causes of things, and from all these to the nature of imperceptible things and finally to hypothetical philosophy.

Draft No. 5 (1 p. 540r) Add. 3965. 13

This sheet contains Definitions of body and vacuum which are the same as those of the earlier drafts. Accordingly I shall not give a translation, but the Latin will be found in the Appendix. The amplificatory remarks appended to the definition of body are considerably shorter than those of Draft 3, not including any of the ideas which come after the reference to 'mathematical solids' in that Draft. The definition of vacuum and the supporting remarks are, however, the same as in Drafts 3 and 4. Thus NEWTON has formulated his ideas in final form. At the top of the sheet is written 'Corrigenda et addenda in Lib. III Princip.' The Definitions were to occupy a place between Regula I and Regula II on the revised Page 357 of the Second Edition. In any event there is a line drawn through both Definitions on the sheet: and they do not reappear in subsequent revision sequences of the Third Book.

We are now in a position to attempt to date these documents. The most obvious fact is that the pagination on some of the manuscript sheets matches that of the Second Edition: thus, the intended emendations were made after 1713. Yet, we cannot assume without question that they were written sometime just prior to the publication of the Third Edition in 1726. For it can be established, I think, that NEWTON had ample motivation for formulating these Definitions earlier.

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[53] NEWTON has marked a space here with three dashes. As suggested above, he probably intended the list of bodies to be copied in here from one of these drafts.

[54] There is a line drawn through the bracketed material. See my remarks above.

[55] This bracketed sentence has two lines drawn through it.

Since KOYRÉ & COHEN have shown that the extent of NEWTON'S involvement in the development of the LEIBNIZ-CLARKE controversy was considerable, and since the doctrine of the void is fundamental to his thought, it is reasonable to assume that he would have been especially aware of any Leibnizian criticism of this theory.

If successive exchanges on the void are compared, it becomes apparent that they converge to a critical point, the most detailed and extensive criticism from LEIBNIZ occurring in the fifth letter of August 18th 1716.[56] Here he argues, as we have seen, from what he takes to be empirical evidence. There can be little doubt that NEWTON thought these criticisms to be wide of the mark, the result of insufficient physical insight. But LEIBNIZ twice repeats[57] in his letter the same criticism that he had made earlier in the "Apostille" to CONTI; namely, that the notion of atoms and the void is an *hypothesis* based on an "easy" and "superficial" philosophy, the result of "limited" metaphysical views.

This "Apostille" was sent with a letter to CONTI about the 6th December 1715, and embodies a general attack on NEWTON'S natural philosophy.[58] The Leibnizian letter to CAROLINE, which is similar in character, was sent at the same time, and CLARKE'S response began the controversy on natural philosophy. In preparing a reply to LEIBNIZ'S Apostille to be sent via CONTI, NEWTON wrote no less than twelve separate drafts, in two of which he mentions that LEIBNIZ denies the conclusion that the vacuum exists without rebutting the premises from which he (NEWTON) argues.[59] Thus the implication is that the charge of having a shallow metaphysics is irrelevant criticism. The letter actually sent to LEIBNIZ on the 26th February 1716 was shorter than most of these drafts. It strongly stated, however, that any doctrine NEWTON would defend in natural philosophy was based on "arguments of induction drawn from experiments".[60]

Yet, not only were the same "philosophical" arguments used against the doctrine of the void in the *Correspondence*, but, as we have seen, in the "postscript" of LEIBNIZ'S letter to CAROLINE on the 12th May 1716, — wherein he made the arrogant assertion that he accepted atoms and the void as a young man — the Newtonian void is again strongly criticised on philosophical grounds. We have manuscript evidence to show that NEWTON received this postscript from CAROLINE and that he copied it out in full.[61] Its tone, style and character must have annoyed him beyond measure.

Thus this philosophical thrust along with the nature of the criticisms of atoms and void in the fifth letter, probably caused NEWTON to draft the Definitions some-

[56] The Fourth letter contains a fair number of criticisms of the void; but these are consequences of the general discussion of space.

[57] ROBINET, *Op. cit.* pp. 135—136, p. 181. Where LEIBNIZ says that neglect of the principle of sufficient reason leads to "l'origine des chimeris, comme par example d'un temps ou, d'un espace absolu réel, du vuide, des atomes ..."

[58] *Ibid.* p. 41.

[59] KOYRÉ & COHEN, *Op. cit.* p. 73, p. 110. All twelve drafts are published in this substantial article.

[60] H. G. ALEXANDER, *The Leibniz-Clarke Correspondence*, Manchester, 1956, p. 187.

[61] ULC. Add. 3968. 36. Fol. 517 at the bottom of the sheet on which the postscript is copied in French by NEWTON, we find, "Received of ye Princess May 7th 1716. *Vide* KOYRÉ & COHEN, *op. cit.* p. 81.

time towards the end of 1716, during the last stage of the controversy or just after it. As we shall see this interpretation is supported by the nature of the remarks to the Definitions themselves, and by other related documents which record NEWTON'S opinion of LEIBNIZ'S theory of matter.

IV

It is now time to discuss the Definitions themselves attempting, where possible, to relate them to the body of published writings. The first thing to notice, on considering the various formulations, is that the terms body and void are interdefined: they are, in fact, treated as correlative terms. What one is, the other is not. Body is tangible, impenetrable, movable, that which acts and offers resistance; whereas, void space has contrary qualities: intangibility, penetrability, immovability, passivity, and hence offers no resistance.

There are a great number of treatises on natural philosophy written in England during the seventeenth century which, as a result of accepting one or other of the many expressions of the mechanical philosophy, either define or use body and void as correlative terms. The origin of this formulation is, of course, to be found in such ancient writers as DEMOCRITUS, EPICURUS and later LUCRETIUS, all of whom had throughout this period a decided influence on the character and development of English natural philosophy. Thus neither NEWTON'S definitional treatment of the terms, nor the philosophical view which lies behind it is original. It was he, however, who first translated this view, in part, into an effective natural philosophy of the perceptible world resting on an impressive basis in experience. It will be important, then, to consider historically some of the influences that may have led NEWTON to this commitment.

Many of his problems and characteristic doctrines were formulated in his early years towards the end of, and just after his undergraduate days, when his creative intellect burned intensely. This is certainly so with regard to his theory of sensible matter, which then remained essentially the same throughout successive refinements of his philosophical position. It is therefore, to this early period in his intellectual development that we must turn in order to establish influences on the formulation of his views. Apart from its intrinsic interest this investigation will provide part of the necessary background for an analysis of the Definitions themselves.

There are two key texts; the *Quaestiones quaedam Philosophicae*, entries in which were made about 1664, NEWTON'S last year as an undergraduate; and *De Gravitatione*, written no later than 1670.[62] These works are by no means equivalent: the setting and purpose of each is different. But they do deal with many of the same questions and in the same spirit. Professor WESTFALL has argued, convincingly, that the Gassendist influence on NEWTON in the *Quaestiones* is more decisive than the Cartesian.[63] This influence was probably through the mediation of CHARLETON'S *Physiologia*,[64] a work saturated with Gassendist ideas, there being no direct evidence that NEWTON had read either GASSENDI'S *Syntagma Philosophi-*

[62] The *Quaestiones* are found in ULC. Add. 3996 and *De Gravitatione et Aequipondio Fluidorum* is published by the HALL'S. *Vide.* Note 15.

[63] RICHARD S. WESTFALL, "The Foundations of Newton's Philosophy of Nature", *Brit. J. for the Hist. of Sc.*, 1962, I: pp. 172—182.

[64] W. CHARLETON, *Physiologia Epicuri-Gassendi-Charltoniana*, London, 1654.

cum or the earlier *Philosophicae Epicurae Syntagma* as an undergraduate.[65] The nature and character of the theory of void space developed in *De Gravitatione*, however, strongly suggests that NEWTON by this time had read the *Syntagma* and that he had also been influenced by the writings of HENRY MORE.

In both these early texts it is evident that NEWTON accepts the existence of void spaces and the antithetical character of the terms 'body' and 'void'. In each case he uses the traditional arguments against the plenum as found in CHARLETON and GASSENDI.[66] There are, furthermore, terminological similarities in the expression of these arguments. In the *Quaestiones* we find reference to the interstitial vacuum made by such phrases as 'vacuities interspersed' and bodies 'divided by interspersed inanities'.[67] Also phrases such 'vacuum disseminatum', 'vacuo inter ... corpuscula disseminato' and 'extramundana spatia' support the view that GASSENDI influenced NEWTON'S discussion, in *De Gravitatione*, of motion in non-resisting media. It must be noted, however, that by this time NEWTON is using these phrases primarily as a means of describing his own theories and, unlike GASSENDI, is in no way interested to formulate the distinction between the *vacuum separatum*, the *vacuum disseminatum*, and the *vacuum coacervatum* as an end in itself.

There is, however, an important difference in the two works with respect to the Newtonian commitment to the void. In the *Quaestiones* he only affirms the existence of void interstices in matter. There is no evidence that he had come to accept a complete celestial void.[68] In *De Gravitatione*, arguing against the Cartesian identification of matter with space, he holds space entirely devoid of matter to be a distinct physical possibility; moreover, with regard to movements in the heavens he says: —

> If there were any aerial or aethereal space of such a kind that it yielded without resistance to the motion of comets or any other projectiles I should believe that it was utterly void.[69]

NEWTON is well on his way to regarding the celestial void as a fact of nature.

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[65] *Opera Omnia*, Vols. I and II ed. T. GREGORY.

[66] CHARLETON, *op. cit.* Chap. IV, pp. 21—50 and Chap. III, p. 19. P. GASSENDI, *Syntagma Philosophicum* Vol. I, *Sect.* I, *Lib.* II, *Cap.* III, pp. 192—196. With respect to the *Quaestiones*, it is more probable that if GASSENDI influenced NEWTON at this early stage it was the *Philosophia Epicuri Syntagma* Vol. III, *pars secunda-Cap.* I. pp. 11—12.

[67] *Quaestiones* Folios 88^{v}, 89^{r}, 89^{v}, 97^{r}, 114^{r}. It cannot be maintained that NEWTON acquired this language exclusively from CHARLETON or GASSENDI. Such expressions were widely used in the plenist-vacuist controversy of the first half of the seventeenth century. See C. WEBSTER, "The Discovery of Boyle's Law and the Concept of the Elasticity of Air in the Seventeenth Century", *Arch. for History of Exact Sciences* **2**, 441—502 (1966). Also, such phrases are used by STANLEY in his *History of Philosophy*, London, 1655—62, part 5, 1660, pp. 144, 154, 159 and 178, which was read extensively in this period. However, since many of NEWTON'S doctrines seem to come from CHARLETON and GASSENDI, it is probable that the terminology was, in the first instance, taken from them.

[68] This is not surprising, for at this stage NEWTON still accepted the Cartesian Vortices.

[69] HALL & HALL, *op. cit.* p. 146. On page 147, NEWTON says 'Since the resistance of the aether is on the contrary so small when compared to the resistance of quicksilver ..., there is all the more reason for thinking that by far the largest part of the aetherial space is void, scattered between the aethereal particles'.

In both works the contrariety of void and body is accepted, though in *De Gravitatione* it is more explicit than in the earlier work. There it emerges from NEWTON's discussion of the motions of bodies, the assumption being that that in which they move must be opposite in nature.[70] CHARLETON, discussing 'inanity' in the context of motion, says: —

Epicurus names it a *region*, or *space*, and *a Nature that cannot be touched:* thereby intimating the direct contrariety betwixt the essential notion of Corporiety and Inanity: which antithesis *Lucretius* plainly expresseth in that verse, *Tactus Corporibus cunctis intactus Inani.*[71]

Since some of the discussions of motion in the *Quaestiones* display an anti-Aristotelian bias, it is possible that passages such as the above remained fixed in NEWTON's mind from his reading of CHARLETON's *Physiologia.*

With *De Gravitatione* the discussion of space and matter becomes at once more philosophical and theological. One of the central aims is to bring out the categorical difference between these notions. Such passages as the following from the *Syntagma* may well have influenced NEWTON's view regarding the difference between perceptible matter and void space: —

: ... cum circa Rerum divisionem memoravimus Epicurum, & cum ipso Lucretium Universum seu naturam rerum in Corpus, Inanéque partiri, Exinde enim habetur corpus ita ab Inani distingui, ut cum Inane sit molis expers, intactile, incapax actionis, passionis, resistentiae; Corpus sit mole praeditum, tactile, actionis, passionis, resistentiae capax.

And at the end of the same paragraph GASSENDI says: —

ex horque est illa apud Lucretium Antithesis, qua convenire dicitur *Tactus corporibus cunctis, intactus Inani.*[72]

Unmistakably then, GASSENDI holds the view that body and void are correlative terms. There is an elaborate development of this in Books II and III of the *Syntagma.* Throughout, GASSENDI's analysis is set within a broad sceptical framework. We cannot have certain knowledge of matter; its real nature is beyond understanding. Experience alone gives us the properties of matter, and also shows that it is essentially different from space. If matter is finite, there must exist something greater than itself which it occupies; this is void space infinite in extent.

While in *De Gravitatione* NEWTON largely accepts the sceptical epistemology of GASSENDI regarding the phenomenal world,[73] it is MORE who most probably in-

[70] *Quaestiones.* Folio 114[r].

[71] CHARLETON, *op. cit.* p. 17. He is, of course, only repeating, in part, GASSENDI's elaborate discussion in Bk. III of the *Syntagma.*

[72] GASSENDI, *Syntagma,* Vol. I p. 231. Similar passages are to be found on pp. 230 to 232 and on pp. 180, 184, 185 of *Lib.* II. In the earlier *Philosophiae Epicuri Syntagma, Pars Philosophiae Secunda, Caput* I, p. 11, the doctrine is expressed in a similar way. The influence of HENRY MORE in this respect cannot be overlooked. The correlative nature of these notions is clearly expressed in several places in his writings. In *A Collection of Several Philosophical Writings of Dr. Henry More,* London, 1712, *Vide* the *Epistola Prima H. More ad R. Cartesium,* p. 62; the *Immortality of the Soul,* Chap. III, pp. 8—9, Chap. VII, pp. 25—28, and Chap. XI pp. 40—43. In the *Divine Dialogues,* 1668, MORE says, with reference to the reality of infinite extension, 'This evidently demonstrates the existence of the ancient *Democritish Vacuum,* and withall that Extension and Matter are not convertible terms, for which Cartesius so much contends.' p. 103.

[73] Professor WESTFALL has urged this view in his 'Newton and Absolute Space', *Arch. Inter. d'his. des Sc., Numero* 67, Avril—Juin 1964, pp. 121—132. However, as I shall attempt to show, the thesis needs important qualification.

fluenced the general principles of his account of the creation of matter. In terms of an imaginative hypothesis NEWTON suggests that it is possible that God by an act of will could have endowed empty spaces with the sensible properties of matter such as impenetrability.[74] In appearance it would be no different from what it is. The essential point so far as NEWTON is concerned, however, is its contingent nature. Its existence is utterly dependent on the will of God. This is made clear from the following passage on body: —

> For certainly whatever cannot exist independently of God cannot be truly understood independently of the Idea of God. God is no less present in his creatures than they are present in the accidents, so that created substance, whether you consider its degree of dependence or its degree of reality, is of an intermediate nature between God and accident. And hence the idea of it no less involves the concept of God than the idea of accident involves the concept of created substance.[75]

Thus in comparison with the necessary existence of Space and God, matter is an entirely impoverished being embodying the lowest degree of reality and perfection. Hence the 'downgrading' of matter is clearly a stated assumption of NEWTON's position and plays an important role in his discussion. As MORE puts it, "From the highest life viz, the Deity, there does result that which has no life or sense at all, to wit, the stupid matter".[76] These themes recur often in the *Immortality of the Soul*, a work which NEWTON certainly read.[77] That he still accorded matter the lowest degree of reality and perfection in his system some four decades later, just prior to the *Correspondence*, is attested by a passage from a letter of CONTI to

[74] HALL & HALL, *op. cit.* pp. 139—140. Although there is no direct evidence that NEWTON read MORE's *Divine Dialogues* the *manner* in which the doctrines of of *De Gravitatione* are expressed is mindful of the first Dialogue. This dialogue is MORE's mature expression of his position, and the whole discussion is anti-Cartesian in a vein similar to NEWTON's treatise. Moreover the leading doctrines expressed are closer in character to those of *De Gravitatione* than in any of MORE's earlier treatises. God's omnipresence, his identification with space, the reality of general extension (this is the first time that MORE argues for this position), the 'vital congruity' of spirit and matter, that everything, including spirits, must exist 'somewhere', *etc.* Thus it is quite probable that NEWTON knew this treatise. Accordingly his theory of the manner of matter's creation could have occurred to him on reading the first Dialogue. After the Platonist Barthnous argues that general extension (space) is a necessary existent, utterly distinct from extended *things*, and the only ground for the existence of an infinite Spirit, Cuphophron suggests that 'Extension is the *Capacity* of matter'. Barthynous then asks, 'What do you mean by Capacity, Matter *in potentia*?' p. 108. The idea is not pursued; but in the context of the discussion, where it is repeatedly affirmed that matter is a dependent existent moved by God's will, we surely have the germ of NEWTON's hypothesis, namely, that space is the potentiality of matter made actual when determinate parts of space are made to manifest sensible appearances. If this suggestion can be substantiated, WESTFALL's assertion that 'Newton's empty spaces moved about by God are the direct product of Gassendist skepticism', WESTFALL, *op. cit.* p. 129, can no longer stand.

[75] HALL & HALL, *op. cit.* p. 144. CLARKE makes the same point in different terms '... if *Extension* were the Essence of Matter, and so *Matter* the same as *Space* itself: it would follow that Matter is infinite, and necessarily eternal, and could neither have been created, nor reduced to nothing; which is very absurd.' *Vide.* Note 10, item *Rohault*, Vol. I, p. 24. The passage in the text makes it plain that NEWTON regards matter to have even less reality and perfection than accidents, by which he probably means properties. For the epistemology supporting this, see Section VI below.

[76] MORE, *A Collection. Immortality of the Soul* II:XI:10.

[77] *Quaestiones*, Fols. 89, 104, 105, 117 and 132.

RÉMOND, extracts from which were sent to LEIBNIZ. In the course of a summary of NEWTON's philosophy, based on actual conversation, CONTI says: —

L'Espace n'a aucun changement comme les corps; et comme il contient les corps, qu'il est le lieu des corps, qu'il est eternel, qu'il est immense, il a bien plus de perfections que les corps. Si vous demandez ce qu'il y a dans les espaces vuides de matiere, les newtonistes vous repondent, que comme l'espace est une proprieté de la divinité, il y a tout ce qui accompagne la divinité.[78]

Thus NEWTON's account of the creation of matter vividly dramatises the lowly status that it has in his natural philosophy. Moreover, the later stress on its paucity in favour of the void on the part of NEWTON and his disciples, is yet another expression at a different level of this theologically orientated world view originating in the writings of MORE and the Cambridge platonists. A still more fundamental expression of this attitude is involved in the doctrine of matter's passivity. There is sufficient evidence to show that NEWTON plumped for 'infinitely' hard bodies as the basic constituents of the actual world. If matter is inert and hard in the Newtonian sense,[79] this entails that it has the property of non-elasticity. Immediately this precludes the Leibnizian solution of dynamical activity in the world, since this view entails that the defining characteristic of ultimate matter is *elasticity*. Clearly this theory allows matter from the theological point of view to be more independent of God, activity being in some sense inherent in it. Thus not only would a force inherent in bodies and conceived as *vis viva* open the door for atheism in NEWTON's view,[80] but it would also grant matter more reality and perfection.[81] Both consequences are inimical to his theology and ontology; and probably explain in a general way, apart from technical objections, his unsympathetic attitude towards LEIBNIZ's dynamics.

The major intellectual forces which probably led NEWTON, by 1670, to an acceptance of void space and its antithesis to matter have been indicated. It will now be helpful to consider briefly this commitment as it develops from the time of the First Edition of the *Principia* to the time of the Definitions. From what has been said it is plain that NEWTON's correlative use of the terms void and body presupposed a definite view of the world, and thus was not merely a matter of definitional convenience. Hence an attempt to combine the scattered elements of the conceptual background relating to these Definitions, will help to characterise

[78] ROBINET, *op. cit.* p. 19. The letter is dated 18th October.

[79] NEWTON includes both impenetrability and non-deformability in the meaning of the term. But since impenetrability does not exclude deformability, what he means essentially by the term is non-deformability.

[80] 'Indeed, however we cast about we find almost no other reason for atheism than this notion of bodies having, as it were, a complete and absolute and independent reality in themselves.' HALL & HALL, *op. cit.* p. 144. This view is commonly found in English Natural Philosophy of the period. With NEWTON, however, it is a basic principle. In an early draft of Query 31 he says:

... matter depends upon a Deity for its laws of motion as well as for its existence. The Cartesians make God the author of all motion and it is as reasonable to make him the author of the laws of motion. Add 3970, F. 243r. And in a draft version of the *General Scholium:* Materia non est aeterna sed originem habuit a voluntate Dei. Add 3965, 13 [150—182] F 547r. See also Note 75.

[81] Notice how this view of matter is diametrically opposed to that of LEIBNIZ, who clearly states that the more active matter there is in the world, the more reality and perfection. *Vide.* sections II and V.

the deeper substrata supporting the natural philosophy of the Third Book. Also such a reconstruction may indicate the inter-connections which these elements had for NEWTON when he drafted the Definitions.

The question that now needs clarification is this: in what sense does NEWTON think that body and void are correlative terms? I must first indicate by example two basically different senses in which terms may be described as correlatives. The terms 'husband' and 'wife' illustrate the strongest possible relation. If the term 'husband' has significant application, then it necessarily follows that the term 'wife' has as well, and conversely. With the terms 'hot' and 'cold' the relation is weaker. If it is significant to say that something is hot, then the term cold has significance and conversely. This does not entail, however, that nothing can be hot but that something else is cold; but only that if the term 'hot' has application then it is possible that the term 'cold' has as well, and conversely.[82] Thus it is clear that the stronger relation entails the weaker: the converse, however, does not hold. Some important controversies in the history of natural philosophy have centred on the nature of correlative terms. For example, the Peripatetic philosophy treated 'gravity — levity' as correlatives in the stronger sense. The 'corpuscularian' opposition of the seventeenth century admitted the symmetry of significance, but denied the existence of 'levity' altogether.

I shall argue that in the Third Book, NEWTON uses the terms 'body' and 'void', as applied to the sensible world, in a sense which admits a symmetrical relation of significance, namely, the weaker relation. At a deeper level, however, his view of the connection between void space and matter does not accord with the way the terms in either example have application. My procedure will be to consider some characteristic physical doctrines which use these concepts, to analyse the philosophical assumptions which lie behind them, and to indicate some of the empirical facts which the entire 'theoretical' framework was devised to explain.

We have seen that the doctrine that differences in weight and density are to be explained by the ratio of interstices to solid parts in matter, and the view that planetary motions are impossible in fluid media, vortically structured, both presuppose that as a matter of fact vacuities exist in nature: thus no matter without void. This position is brought out more forcibly by the following two physical doctrines.

For NEWTON it is an indisputable fact that solar bodies move along their orbits as a result of mutual gravitation towards one another and towards the sun. Dynamically it is equally incontestable that this action and reaction is analysable into an inertial and a centripetal component. CLARKE concluding a summary of this view, says of bodies which satisfy the above conditions: —

> ... that the space betwixt them is void, that is, hath nothing in it which sensibly resists the Motion of Bodies passing transversally through: All this, is nothing but PHAENOMENON OR ACTUAL MATTER OR FACT, found by EXPERIENCE.[83]

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[82] In either case there is a logical connection of significance between the terms; but the modalities are different. In the first case the connection is one of necessity; in the second it is one of possibility. Put notationally we have: A is correlative to B $df \Diamond(\exists x) A x \underline{\underline{\vdash}} \Diamond(\exists x) B x$. And in the second case $(\exists x) A x \underline{\underline{\vdash}} (\exists x) B x$.

[83] ROBINET, *op. cit.* p. 209—210.

But NEWTON also holds it to be an 'actual matter of fact' that if the solar bodies move according to Keplerian laws which in turn follow demonstrably from the law of gravity as it mathematically describes the effects of such a force, this force: —

> ... operates not according to the quantity of the surfaces of the particles upon which it acts (as mechanical causes used to do) but according to the gravity of the solid matter which they contain ...

and thus

> penetrates to the very centres of the sun and planets, without suffering the least diminuition of its force.[84]

NEWTON certainly thought in the early 1690's that it was possible to give a mechanical explanation of gravity along the lines of FATIO's hypothesis. This involved the postulation of a great number of vacuities in matter.[85] But it seems that the mechanical aether of the 1717 edition of the *Opticks*, in order to give an account of the operation of gravity within bodies, is also committed to this hypothesis. There is, however, a grave difficulty, which probably accounts in part for the fact that NEWTON abandoned FATIO's hypothesis, and that he may not have taken his own aethereal medium seriously. For if gravity is as the total quantity of matter of any solid body, large or small, then it must be possible for its action to pass entirely through such bodies. But it is plain that such action cannot be explained by the hypothesis that bodies are extremely rare, since it is the operation of gravity on *solid* matter that is in question. Nevertheless this seems to be the only hypothesis available to NEWTON as a means of explaining how his mechanical and material aether is able to act on bodies. Thus in 1716 when he drafted the Definition of void space and was entertaining an aethereal medium as a means of explaining gravity, he may still have thought that such an hypothesis was plausible in principle. Accordingly some hypothesis involving the existence of voids *in* bodies is to be granted so as to account for, in terms of an aethereal medium, the action of gravity upon them.

Again from the demonstrations of Books II and III it is plain that only in spaces void of resistance would planetary bodies falling under NEWTON's laws move in elliptical orbits. These laws were formulated in terms of precise and well attested Newtonian concepts: the proportionality of inertia to gravity and of both to the quantity of matter. Thus the total conception of discrete bodies or particles interacting with one another according to a definite function of the

[84] CAJORI, *op. cit.* p. 546.

[85] After stating that if the particles of bodies were pressed together 'in a compact mass like grains of sand or a heap of stones' the force of gravity would tend less to the inner than the outer ones, thus violating the proportionality of gravity to matter, NEWTON says, 'Other textures of the bodies must be devised by which their interstices are rendered more ample, and this is the necessary condition of an Hypothesis by which gravity is to be explained mechanically.' HALL & HALL, *op. cit.* p. 315. It is necessary, however, to be cautious about NEWTON's complete acceptance of the hypothesis even in the 1690's; for we have FATIO's own testimony to the effect that NEWTON 'did not scruple to say *that there is but one possible mechanical cause of Gravity, to wit that which I had found out.* Thô he would often seem to incline to think that Gravity had its foundation in the arbitrary will of God ...' *Vide.* Note 19, *Notes and Records*, p. 117. But on the other hand, notice NEWTON's comment to LEIBNIZ in 1693 *Correspondence*, Vol. III, p. 287, 'But some very fine matter seems to fill the heavens.' And if all the laws of motion can be shown to be compatible with it, NEWTON says he is 'far from objecting'. Again this is evidence of a state of vacillation.

distance separating them, presupposes the near vacuity of the intervening spaces. Any vortical fluid, such as the Cartesian or Leibnizian, as NEWTON shows in Section IX[86] of Book II, would be incompatible with the only system that accounted for them dynamically — the Newtonian. NEWTON in his criticism of the *Tentamen* which draws on this Section of the *Principia*, puts the matter unambiguously.

> Quae de Vorticibus dicuntur sunt merè hypothetica, & cum motu Cometarum conciliari non possunt, neque quadrant cum Planetarum temporibus periodicis quae sunt in ratione sesquiplicata distantiarum ab orbium centro communi.[87]

So much for the triumph of Newtonian dynamics with regard to the perceptible world. But NEWTON'S own tentative explanation of the cause of gravitational attraction, in 1717, by means of an 'aethereal medium' was bedevilled by conceptual tension. Detailed discussion of this issue is beyond the scope of the present paper, but since the cosmological implications of this aether affect the doctrine of celestial voids, the following difficulties must be mentioned. Given the Newtonian account of differential densities discussed in Section I, and given that the aether is material in nature, how can the theory that the aether is "much rarer within the dense bodies of the Sun, Stars, Planets, and Comets, than in the empty celestial spaces between them? And in passing from them to great distances", grows "denser and denser perpetually?"[88] be reconciled with the view that matter in these spaces becomes rarer and rarer as distances increase? Secondly, so as not to hinder the passage of planets NEWTON must also hold that the gross aether has an extremely small density. How then can it possibly transmit gravitational influences, especially when other sorts of vibrations, such as sound, must be 'propagated through the solid, pellucid and uniform Capillamenta' of the nerves?[89]

[86] CAJORI, *op. cit.* pp. 385—396. Especially important are the corollaries and scholium for Proposition L11, and Proposition L111 of Book II. The main charges against the vortex theory are: the radical instability of the system (the corollaries to Prop.L11), the fact that whether the planets move through, or with the vortices (LEIBNIZ'S 'harmonic motion') the third law of KEPLER is violated, and that the areal law would also have no application. COTES gives a very clear account of these criticisms in his Preface to the second edition. He especially stresses the irregularity of the motions of the Comets as evidence against vortices. *Vide.* Bk. III.

[87] EDLESTON, *op. cit.* p. 310. *Ex Epistola cujusdam ad amicum.* This manuscript was not published during the controversy. It gives a clear indication of NEWTON'S commitment to the void.

[88] *Opticks. op. cit.* p. 350.

[89] *Ibid.* p. 353. The real difficulty here is not that of understanding how an aether of small density can *quantitatively* transmit gravitation as L. ROSENFELD suggests [Further Papers of Isaac Newton. *Nature* **196** (1962)] but how such a medium can transmit any influence at all. This is especially so in view of the fact that NEWTON repeatedly states that very dense media are necessary for maintaining vibrations and for propagating them quickly. *viz. Opticks* p. 344. J. LOHNE in an important article, 'Newton's theory of colours', *Arch. for the Hist. of Ex. Sc.* **1**, 402 (1961), has suggested that NEWTON gave up the cosmological aether because it was incompatible with the exact application of the inverse-square law, which indicated a non-resisting void. Again, ROSENFELD has suggested that he restricted its operation to short-range interactions in his theory of light and colours, 'Newton and the Law of Gravitation', *Arch. for Hist. of Ex. Sc.* **2**, 385 (1965). I agree with this. And these difficulties, in conjunction with those indicated above, make it difficult to explain why NEWTON outlined such an elaborate hypothesis in the Queries of 1717; unless of course to attempt an explanation of the independent existence of Forces. Professor GUERLAC'S view — apart from the great merit of his papers — that he did so as a result of HAUKSBEE'S

Leaving these special difficulties aside, we can find other theoretical considerations which will throw light on NEWTON's position regarding these correlatives. The first is his theory of force. NEWTON often states that gravity is a real physical force in nature:[90] and he denies, moreover, that it is inherent in matter. It is therefore something of an independent nature which operates on bodies, its properties in no way being reducible to them. For matter can only react to such a force, never originate it. So, at least from the time of the *Principia* NEWTON began to think of the world in terms of a richer ontology than that of matter in motion.[91]

This can be further clarified in contrast to the Cartesian view of force. DESCARTES tended to assimilate the concept of force to the description of relative changes of position between bits of matter. Such changes for NEWTON could be no more than effects, the manner in which forces are acting, which can be treated mathematically in terms of magnitude, direction, and quantity of matter. Although he would agree with DESCARTES that forces can be dealt with only in so far as their effects are observable, this in no way reflects, as it did for DESCARTES, what he meant by the term. In short, NEWTON's was not a positivistic notion of force, but a realistic one.

What implications does such a view of force have for his theory of void space and matter? Since forces are real existents, they must be physically present somewhere. Being of a different ontological type from matter they are neither assimilatible to it nor one of its essential attributes, nor in any sense inherent in it. The only alternative for NEWTON was to suppose that they operate on inert matter in void space. Thus the doctrine of a hierarchy of forces ranging from the subsensible to the sensible world requires void space as a physically real existent.

The same point is made, at a more philosophical level, with the theory of absolute space. I shall not deal with the doctrine as presented in the *Principia* but turn to *De Gravitatione* where the essential features of the position are to be seen clearly. There, as we have noted, NEWTON strongly objects to the Cartesian theory of matter. Now this position takes the occupancy of space, that is voluminousness or geometrical solidity, to be the essential attribute of matter. Thus DESCARTES regarded empty space without any matter in it as a demonstrable impossibility. For being spatial was a logically sufficient as well as necessary condition of being material.[92] Plainly, then, matter and space are identical: equally plainly NEWTON

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work on electrical and magnetical phenomena is of little help in the light of such conceptual dilemmas. H. GUERLAC, 'Francis Hauksbee', experimentateur au profit de Newton', *Arch. Inter, d'his. des Sc.* **16**, 113—128 (1963) and 'Sir Isaac and The Ingenious Mr. Hauksbee' *L'aventure de la Science, Melanges Alexandre Koyré*, Vol. I, Paris 1964, pp. 228—253.

[90] HALL & HALL, *op. cit.* pp. 305—308 317, 333, 341, and 345. *Opticks.* Query 31. pp. 389—390, 395 and 397, the Preface to the first edition of the *Principia*, and many other references scattered throughout the published and unpublished writings.

[91] In his *Waste Book* Add. 4004, 1664, which contains many dynamical writings, NEWTON seemed to conceive the programme of the mechanical philosophy as extending the machinery of matter and motion, as treated mathematically in impact phenomena, to *all* natural phenomena. Some time in the 1680s, he came to the view that many phenomena cannot be treated in terms of such a narrow conceptual framework. Thus he enriched the 'classical' mechanical philosophy with the category of force.

[92] DESCARTES, *Principia Philosophiae, pars secunda*, art. 10, *Ouevres*, Vol. VIII, p. 45, ed. C. ADAM & P. TANNERY, Paris, 1897—1913.

repudiates this and the theory of knowledge which supports it. For he argues in the manner of GASSENDI,[93] CHARLETON and MORE,[94] that neither space nor time can be comprehended under the traditional categories of substance and attribute. As CHARLETON puts it: — "We say *more general than these two* because as well all substances or accidents whatever, have both their existence in some place and their duration in some time."[95] Thus in the Newtonian view void space, far from being a mere conceptual entity, has the most general mode of existence: — "For it has its own manner of existence which fits neither substances nor accidents".[96]

NEWTON also holds that void space, being an unconditioned entity,[97] is ontologically more basic than its material content. Consider the following passages from *De Gravitatione*: "But it is usually believed that these spaces are nothing: yet indeed they are true spaces. Although space may be empty of body, nevertheless it is not in itself void; and *something* is there, because spaces are there, although nothing more than that."[98] And a few pages earlier we find the following: —

> Moreover, since we can clearly conceive extension existing without any subject, as when we imagined spaces outside the world or places empty of body, and we believe (extension) to exist wherever we imagine there are no bodies, and we cannot believe that it would perish with body if God should annihilate a body, it follows that (extension) does not exist as an accident inherent in some subject.[99]

Thus NEWTON following GASSENDI, CHARLETON and MORE is arguing that void space, which is incorporeal, is a physical reality. Moreover space, being independent of body, could exist even if body were destroyed. The latter, however, essentially depends for its existence on the former. Therefore void space is a fundamental ontological category, a necessary condition for the existence of bodies *qua* extended things.

From the foregoing analysis it is clear that NEWTON could not have regarded the terms body and void as correlatives in the strong sense but only in the weak sense in which the significance of terms is mutually presupposed. This means that just as something can be hot without something being cold, so it is possible that something could fall under the concept of void space without something falling under the concept of matter. There is an important difference in the two cases however. In the first case something may be hot without something being cold and conversely; but according to the basic principles of NEWTON's ontology this

[93] *Syntagma Philosophicum, Opera Omnia*, Vol. I, *Liber Secundus, Cap.* I. p. 179.

[94] MORE, *A Collection. Epistola Prima H. More ad R. Cartesium*, p. 62.

[95] CHARLETON, *op. cit.* p. 66. Chapters VI and VII of the *Physiologia* could be shown to be an important influence on Newton's views of space and time.

[96] HALL & HALL, *op. cit.* p. 132.

[97] LEIBNIZ points out in the *Correspondence, Robinet*, p. 136, that for NEWTON space is 'un realité absolué'. KOYRÉ & COHEN agreeing that he is right, clarify the implications by saying that for the Newtonians, 'infinity implies necessity thus eternity'. *op. cit.* p. 90. This does not get to the heart of the matter. For the sense in which NEWTON thought space to be infinite must be made clear. It seems that he held it to be an unconditioned existent. Thus no temporal change or condition could possibly affect its existence; not even the annihilation of the physical world. Hence, in the following sense, it is an infinite and necessary existent: namely, the unconditioned condition for the existence of anything in the world. This is plainly a traditional position.

[98] HALL & HALL, *op. cit.* p. 138.

[99] *Ibid.* p. 132. See also pp. 137—138.

symmetry does not hold with respect to the void and matter. For something could always fall under the concept of void space whether or not matter existed.

Thus at this level, since void space is the most general and basic category, it cannot be for NEWTON a correlative of matter. He allows, of course, that the concept cannot be formed independently of experiencing matter. Since in the *actual* contingent world NEWTON holds that certain empirical facts can only be explained by the physical doctrines discussed, the terms are correlatives in the weak sense as applied to this world by means of these doctrines. Thus with respect to the composition of concrete things it is contingently the case that void does not exist apart from matter. Matter is matter only with reference to some void, and void is void only with reference to some matter.

V

"About other sorts of bodies and other sorts of void let authors in other sciences dispute." Who are these writers from whose views on matter NEWTON wishes to disassociate himself? A necessary preliminary to answering this question is a consideration of his conception of sensible matter with respect to its causal properties. An integral part of this conception is the view that bodies act upon one another and by implication on the sensory organs.[100] It is clear from the various formulations in the Definitions that his aim is to stress the perceptible and tangible aspects of matter. Furthermore, he is concerned with a small but central sub-class of tactile qualities, namely, those of hardness and resistance to touch. These qualities have as an objective counterpart in the physical world solid and tangible bodies which can interact with one another.

There is sufficient evidence to show that NEWTON formulated these conceptions as an undergraduate at Cambridge. For example, in the *Quaestiones* he says: —

> The nature of things is more securely & naturally deduced from their operacions one upon another and upon yr senses. And when by ye former experiments we have found ye nature of bodys, by ye latter wee may more clearely find ye nature of yr senses.[101]

Later in *De Gravitatione* the same view is developed in a more epistemological context. Again it is emphasied that bodies are phenomena, only in so far as they act upon one another and upon the senses. Substance is "an entity that can act upon things".[102] Mere extension cannot do this since contrary to the opinions of DESCARTES, solidity and the power of resistance are not derivable from it.

It can thus be readily seen that NEWTON'S views remained essentially the same from his student days to the early period of his more mature thought; moreover, as the Definitions testify, it remained unchanged throughout his life. The authors whom he read as a student, and who probably influenced him in this respect, held essentially the same doctrines. For example DIGBY, to whom he refers in the *Quaestiones*, says in the opening page of his *Two Treatises:* —

> ... when a man would distinguish a corporeal substance from a spiritual one (which is accounted indivisible) he naturally pitcheth upon our apprehension of its having bulk, and being solid, tangible, and apt to make impression upon our outward senses;

[100] *Opticks. op. cit.* pp. 353—354. HALL & HALL, *op. cit.* p. 132. The same view is clearly developed in NEWTON'S first reply to HOOKE'S criticisms of his theory of colours in 1672. *Vide.* Note 10, item COHEN, p. 118—119.

[101] *Quaestiones* .Folio 101^{v}.

[102] HALL & HALL, *op. cit.* p. 132.

according to that expression of Lucretius, who studying nature ... telleth us *Tangere enim & Tangi, nisi Corpus nulla potest res.*[103]

Similar passages are to be found in the writings of MORE, CHARLETON and GASSENDI. And GASSENDI and CHARLETON also single out this Lucretian phrase as epitomising their view of sensible matter.[104] Although it is nowhere quoted by NEWTON it nicely characterises his point of view.

There are four separate pieces of evidence which indicate that LEIBNIZ was primarily the person whose views of matter NEWTON repudiated. In nearly all the draft variants to the letter sent to CONTI in 1716 he charges LEIBNIZ with changing the meanings of words so as to criticise his views on gravity, the nature of the soul, on hypotheses, and on miracles. In a letter actually sent to CONTI he says: — "As to philosophy, he colludes in a signification of words, calling those things miracles which create no wonder; and those things occult qualities, whose causes are occult".[105] Now in the document under discussion NEWTON is concerned that it be perfectly understood in what sense he understands the terms body and void. In Definition II of Draft No. 2 he puts the matter plainly by stating: — "If any man should contend that bodies are given which by touch are neither felt nor cause a resistance, this man is now disputing the grammatical significance of the word ...". NEWTON'S aim is to ensure "that ambiguity of words will be avoided from whichever arguments of ideas are accustomed to arise". Since the character of the criticism here is the same as that made against LEIBNIZ in the letter to CONTI, it would seem likely that the Leibnizian view of matter is the primary target in these passages.

This suspicion is confirmed. For in one of the variants of the letter to CONTI NEWTON says: "He sayeth that I have not demonstrated a vacuum nor universal gravity nor atoms". Later in the same document we find: —

> He of opinion that space void of tangible body may be full of a corporeal intangible fluid whereas the Ancients believe that all things intangible were incorporeal. I understand tangibility not in a mathematical sense but in a physical sense, such a tangibility as by some resistance (can) affects the sense of touching.[106]

This is precisely the doctrine that NEWTON is defending in the Definitions and consequently rejecting the notion that an intangible but corporeal fluid is a sort of matter. And he does so in much the same manner as in the latter part of the above passage.

From two further sources there is evidence of a more conclusive sort, that NEWTON has in mind not only the CARTESIANS, but also LEIBNIZ and RÉMOND, a follower of LEIBNIZ. First there is an unpublished set of notes by NEWTON defending his natural philosophy against criticism by RÉMOND.[107] This attack, originally a letter to N. BERNOULLI, was printed in the Second Edition of RÉMOND'S

[103] K. DIGBY, *Two Treatises*, London, 1658, p. I.

[104] *Syntagma. Liber Tertius, Cap.* 1, p. 231. GASSENDI'S reference is corrupt. He quotes '*Tangere enim, tangi sine corpore nulla potest res*'. It is interesting to notice that CHARLETON, in the *Physiologia*, quotes it in the same form. DIGBY, on the other hand, is correct.

[105] ALEXANDER, *op. cit.* p. 187.

[106] KOYRÉ & COHEN, *op. cit.* p. 111.

[107] ULC. Add. 3968. 33. Folios 468—470. For details of PIERRE RÉMOND DE MONTMORT see D. BREWSTER, *Memoirs of the Life, Writings and Discoveries of Sir Isaac Newton*, Vol. II, p. 436, Edinburgh, 1855.

Essai d'Analyse sur les Jeux de Hazard in 1713.[108] There a rebuttal of the Newtonian philosophy is directed against the recently published Second Edition of the *Principia*. Among other things RÉMOND is concerned with method, the theory of attraction, and the doctrine of the void, wishing to show that all phenomena can be explained in terms of matter and motion alone.

In these elaborate notes which were probably written in 1714, and the basis of an unpublished letter by KEILL,[109] NEWTON takes issue with RÉMOND on twelve separate points numbered as such. The sixth point is concerned to contest the assertion that Cartesianism is a 'Metaphysicam sanam' and that everything can be explained in terms of moving bodies: the latter view is also attributed to LEIBNIZ earlier in the draft. However in an earlier set of notes[110] for the letter, it is clear that NEWTON intended to examine LEIBNIZ's metaphysics in greater detail. In these he reiterates time and again that experimental philosophy, being based on phenomena, is to be distinguished from metaphysics. He then proceeds to ask what is to be understood by metaphysics: —

> By a healthy metaphysics he (Rémond) understands the Cartesian in so far as it proceeds from innate ideas to the existence of things. But let us hear what Leibniz himself has to say about true metaphysics.[111]

Then LEIBNIZ'S *De Primae Philosophiae Emendatione & de Notione Substantiae* which appeared in the *Acta Eruditorum*[112] for March 1694, is given its full title followed by a quotation from the article which would have comprised nearly half its published length. NEWTON begins his criticism of both metaphysical views by saying: —

> Metaphysics certainly is founded on ideas, ideas and all true philosophy is founded on phenomena & Newton begins from phenomena. Momortus contends that ideas must not be deduced from phenomena but formed with closed eyes *and from dreams of this kind*. He contends further that we must proceed from ideas to phenomena the eyes being opened again so that we may by the help of ideas see the phenomena clearly and distinctly.[113]

Thus in so far as we are doing natural philosophy, says NEWTON ironically, we must begin from the phenomena with our eyes open. This is what both DESCARTES and LEIBNIZ failed to do in NEWTON'S view.

But it is the content of the article, from which NEWTON intended to quote, that is important. There LEIBNIZ makes a plea for greater exactness in the defining and use of metaphysical notions. One of the main motives is to underline DESCARTES' shortcomings as a metaphysician: he failed to attain certainty, and adhered to absurd doctrines such as "putting the nature of corporeal substances in extension". LEIBNIZ then outlines his own theory of force and the essence of matter. This is activity which "seems not to have been perceived clearly by those who have found the essence of bodies to be in extension, alone or together with the addition of impenetrability".[114]

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[108] The letter is copied and in KEILL's hand. Folios 465—467. Add. 3968. 33.

[109] Folios 471—473. There are corrections in NEWTON's hand in the margins of KEILL's letter.

[110] ULC. Add. 3968. 41. Folios 69r—70r.

[111] Add. 3968. 41. Folio 69r.

[112] Pp. 110—112.

[113] Add. 3968. 41. Folio 69r. This passage is translated from the Latin.

[114] *Acta Eruditorum*. 1694, p. 112.

If NEWTON had had to choose between the Leibnizian or Cartesian metaphysics of matter, it is probable that he would have found the latter more congenial. After all the Cartesian system fitted together in a coherent way; whereas the Leibnizian dynamics, especially since it depended for its complete meaningfullness on a deep and difficult framework of metaphysical ideas not easy to grasp systematically, seemed to NEWTON, at least, to have no validity for natural philosophy. Although LEIBNIZ agreed with NEWTON in rejecting the Cartesian theory of matter, he replaced it by non-extended substances, characterised by substantial forms and internal principles of change. Ultimately all of this was embedded in a system of 'windowless' monads in pre-established harmony, a doctrine NEWTON disparages on many occasions.[115]

Since both sets of notes were written about the same period as the Definitions and for the same reason, a defence of his natural philosophy, it would seem clear that LEIBNIZ, his followers, and the Cartesians are those authors who speak of "other bodies". Moreover LEIBNIZ's view in *de Primae Philosophiae,* that metaphysical concepts are "hidden from popular understanding" and must be defined clearly would constitute, for NEWTON, another example that he "colludes in the signification of words".

The other manuscript source has been published by COHEN & KOYRÉ.[116] It comprises two fragments criticising LEIBNIZ's doctrine of motion and force. NEWTON shows himself to be highly familiar with Leibnizian writings on the subject. So as to comment on the views that he is criticising, he refers to a series of articles published by LEIBNIZ in the *Acta:* "The grounds of his error is that he confounds Acta Erudit: ad Ann. 1686 pag. 162; & ad Ann. 1690 pag. 234; & ad Ann. 1691 pag. 439; & ad Ann. 1695 pag. 155 ...".[117] The last reference is the most important for the problem under discussion. For in 1695 LEIBNIZ published the first part of his *Specimen Dynamicum*[118] which is the most mature and extensive discussion of his theories of force and matter. Again DESCARTES is criticised, and, by implication, the view of matter that NEWTON holds: "I found a proof that something more than magnitude and impenetrability must be assumed in body, from which an interpretation may arise". Thus in the light of the above evidence it is plain that, apart from what was said in the *Correspondence,* NEWTON had detailed and first-hand knowledge of LEIBNIZ's theory of matter, and that it was he whom he mainly had in mind as being someone who merely disputed the significance of words and who held a 'metaphysical' theory of matter.

VI

The following two questions now demand consideration. We require to know what NEWTON understands by the term 'phenomenon', and in the light of this to decide how far he is advancing in his remarks, criteria whereby various intellectual disciplines may be classified. As was pointed out above, ordinary terrestrial bodies are phenomena because they have certain causal properties, offer resistance, and

[115] *Cf.* the letter to CONTI, the Review of the *Commercium Epistolicum. Phil. Trans.* Vol. 29. 1715, p. 224, and the Preface to the 1722 edition of the *Commercium.*

[116] KOYRÉ & COHEN, *op. cit.* pp. 118—121.

[117] *Ibid,* p. 120.

[118] *Acta Eruditorum,* April, p. 145—157.

can be described in terms of the four elements in connection with the operations of various agencies. But the heavenly bodies are phenomena because their parts come together by the power of gravity into spherical masses, they either emit or reflect light, and they are subsumable under the laws of motion. In a short unfinished treatise entitled *Cosmography* NEWTON says: —

> The Universe consists of three sorts of great bodies, Fixed Stars, Planets and Comets, and all these have a gravitating power tending towards them by which their parts fall down to each of them after the same manner as stones and other parts of the earth do here towards the earth and by means of this gravity it is that they are all spherical.[119]

He goes on to point out that the fixed stars and the sun shine "strongly with their own heat"; whereas the earth & planets shine "by his light reflected from them". Furthermore all bodies move according to the laws of motion except the fixed stars. Thus we have in this passage the same criteria of materiality applied to heavenly bodies as in the Definitions. And NEWTON may well have drawn on this treatise when drafting them.

Furthermore we have in the remarks to the Definitions a classification of matter in the visible world into terrestrial and heavenly bodies. It must not be supposed, however, that NEWTON is maintaining an ontological distinction in the manner of the Aristotelian tradition; rather, he is concerned to emphasise the different ways by which we come to know through the senses the properties of two classes of physical things. Terrestrial bodies can be handled, felt to offer resistance, and be experimented with. Heavenly bodies, on the other hand, are not amenable to such procedures. Both sorts of bodies, however, fall under the other criteria. Indeed NEWTON'S whole assumption is that in terms of these criteria we are justified in analogically transferring concepts which apply to terrestrial bodies to the heavenly ones.

Although it is patently obvious from NEWTON'S writings that he held phenomena to be known only through sensory experience, nevertheless, because of what he took to be persistent misunderstandings of his position, he felt constrained to define the notion. This he does on three separate manuscript sheets.[120] Since the other formulations do not differ substantially from the one to be discussed, which is on the reverse side of the sheet containing the Definitions of Draft No. 3, special mention of them will not be made. As these Definitions were an intended revision of Page 359 of the Second Edition, the Definition of Phenomena, if the plan had been carried out, would probably have occupied Page 360. It is as follows: —

Definition I

Phenomena I call *whatever can be seen and is perceptible* whatever things can be perceived, either things external which become known by the five senses, or things internal which we contemplate in our minds by thinking. As fire is hot and water is wet, *and*

[119] ULC. Add. 4005. Fols. 21—2. HALL & HALL, *op. cit.* p. 374. As the HALL'S point out, this seems to be a shortish version of '*Phaenomena*', another treatise in the same manuscript bundle: the latter manuscript closely resembles the 'Phaenomena' of the 1713 edition of the *Principia;* cf. HALLS p. 378.

[120] ULC. Add. 3965. 13. Fol. 420^{r}. This sheet also contains definitions of the terms 'hypothesis', 'rule', 'body' and 'vacuum'. Folio 421^{r}, this sheet contains a definition of body similar to the above; and Folio 422^{v}.

gold is heavy, and sun is light, I am and I think. All these are sensible things and can be called phenomena in a wide sense; but those things are *properly called* phenomena which can be seen, but I understand the word in a wider sense.[121]

Apart from the fact that Definition I makes no reference to the uncertainty of hypotheses, and mentions, as example, only one sort of mental activity presupposing personal existence, it is the same in content as the suppressed Fifth Rule of reasoning published by Professor KOYRÉ.[122] The most striking thing about this Definition is the fact that it indicates an acceptance of the Cartesian 'Cogito' argument. In few other places in NEWTON'S writings do we find such positive Cartesian influence. Since Rule V similarly employs this argument it is surprising that Professor KOYRÉ makes no mention of it in his analysis. He is right, however, to suggest that it is a manifestation of 'Lockean' empiricism against the *apriorism* of the Continent. The striking similarity between Definition I and Rule V, argues that they were probably written in the same period; and having the same polemical tone, they would seem to be closely related to the Definitions of body and void and Rule IV of the Third Edition. Thus whether they concern Definitions, Rules or Scholia, *all* of these documents were written with the intention of presenting a systematic reply, in the *Principia,* to LEIBNIZ'S current attacks on his natural philosophy. Thus the Fifth Rule, which was only one of the forms into which NEWTON considered casting his ideas on phenomena, is not primarily anti-Cartesian in spirit as KOYRÉ suggests.

The remarks to the Definitions[123] constitute one of the clearest expressions of what NEWTON considered to be the task and nature of experimental philosophy. If he had decided to incorporate them in the Third Edition along with the projected Fifth Rule they would have set it and the Fourth Rule into clearer relief. It is noticeable that he repeatedly states that his definition of sensible matter is in accord with the views of the 'common people'. Clearly this is a way of reaffirming that the subject matter of the Third Book is the material objects of everyday experience and, by implication, that the *Principia* is not concerned with metaphysics. It is plain, nevertheless, that he is not ruling out metaphysics, but claiming that such considerations do not find a proper place in the realm of experimental philosophy as he conceives it. Neither is he claiming that purely philosophical speculation is to be discredited. For NEWTON could not deny that such speculation has a role to play in the consideration of ultimate questions. Rather he is at pains to point out that such speculation should not be thought to constitute arguments of the same sort as apply to phenomena, or be thought to repudiate their results.

Consequently the remarks are also concerned to distinguish both the subject matter and types of argument to be found in such disciplines as experimental philosophy, mathematics, and metaphysics. It would seem that NEWTON is labouring obvious distinctions in pointing out that the arguments of experimental science are basically inductive in character and, as such, have no rightful place in either

[121] Folio 422^{v}. ULC. Add. 3965. 13. This passage is translated from the Latin.

[122] 'Les regulae philosophandi' *Arch. Inter. d'His. de Sc. Treizieme Annee,* 1960, p. 14. The sheets published by KOYRÉ are to be found in the same section of the *Principia* box as the definitions of 'phenomena', sec. 13 [53—94] F. 417^{r}, 428^{r}.

[123] *Vide.* sec. III.

mathematics or metaphysics. Moreover, he emphasizes it by referring to the fact that different subject matter demands different arguments. Still these remarks have some weight if considered in a wider context.

In an interesting passage from one of the draft variants of the *Scholium Generale* we read: —

> From phenomena we know the properties of things, and from the properties we infer that the things themselves exist and we call them substances: but we do not have any idea of substances. We see but shapes and colours of bodies, we hear but sounds, we touch but external surfaces, we smell odours and taste flavours; but we know the substances or essences themselves by no sense, by no reflex action and therefore we have no more idea of them than a blind man has of colours. And when it is said that we have an idea of God or an idea of body, nothing other is to be understood than that we have an idea of the properties or attributes of God or an idea of the properties by which bodies are distinguished from God or from each other.[124]

This passage in conjunction with the remarks on the Definition of body shows that NEWTON, within the framework of his natural philosophy, is distinguishing perceptible and imperceptible physical bodies from such metaphysical entities as substance. In the passage just quoted he is concerned with the proper object of each sense: that of sight is colour and shape; that of hearing sound; and so on for the other senses. Colours, sounds, odours, and tastes are the objects of immediate perception; and it is by abstracting from these phenomenal properties that experimental philosophy begins.

In contrast to perceptible bodies, however, the primordial particles are clearly not phenomena: nonetheless NEWTON never doubted their existence. Still the problem — as the Third Rule plainly illustrates — was to establish the nature of such bodies. "Without the Third Rule it cannot be proved that all matter is impenetrable".[125] There was no other course open to him but to employ analogical arguments. Such arguments, needless to say, were anchored in direct experience, basing themselves on perceptible characteristics. On the other hand, though from the properties of phenomena we might construct metaphysical notions congruent with them, this would provide no clear grounds that they stood for anything in nature. Similarly from the natural order the existence of God can be inferred. But for NEWTON his complete nature is only revealed, if at all, in the scriptures by exegetical argument and the testimony of the prophets.[126]

Yet another version of the Fourth Rule, quite different from those discussed by Professor KOYRÉ, is specifically concerned with the nature of arguments in different disciplines.

> In experimental philosophy *objections* Hypotheses ought not to be allowed to oppose arguments gathered from experiments by induction, in order that *this is to say* experimental philosophy may not be confused with hypothetical. *Geometrical demonstrations are universal.* Arguments based on induction *they are stronger than hypotheses* are not demonstrations, yet they are stronger than hypotheses; and ought to be reckoned general, except in so far as exceptions gathered from experiment may be met with:

[124] HALL & HALL, *op. cit.* p. 361. A similar, but less elaborate passage is to be found in the *Principia.* CAJORI, *op. cit.* p. 546.

[125] KOYRÉ & COHEN, *op. cit.* p. 113.

[126] In the Keynes Collection of Newtonian manuscripts in King's College Library is the following passage under the heading 'Seven Statements on Religion': 'That religion and philosophy are to be preserved distinct. We are not to introduce divine revelations into Philosophy, nor philosophical opinions into religion.' K. MS. 6.

accordingly when no objections of this kind are met with they ought to be stated as of general application.[127]

This draft is less polemical than both the published Rule and the other manuscript redactions. NEWTON's aim is to characterise the nature of inductive arguments: they need not be general but, in so far as there are no exceptions, they can be held to be so. Plainly they are not to be confused with hypothetical arguments — those of the metaphysics and the natural philosophy of LEIBNIZ — or with mathematical demonstrations: the former are a weaker type of reasoning, the latter are a stronger.

Thus various disciplines have a distinctive subject matter and consequently develop arguments appropriate to their needs. Experimental philosophy is no exception. In NEWTON's view, however, his critics had failed to appreciate this. For this reason he is concerned to say that 'metaphysical and hypothetical entities' are 'more properly treated in metaphysics and hypothetical philosophy'.

In the closing sentences of some of the above documents in Section III, NEWTON suggests that speculative thought, whether it is metaphysical or theoretical, ought to base itself on a sure foundation of experimental philosophy. This is in character with many passages in which he sees his views as providing a basis for natural theology. For instance in Query 28 he says: —

> Whereas the main Business of Natural Philosophy is to argue from Phenomena without feigning Hypotheses, and to deduce Causes from Effects, till we come to the very first Cause which certainly is not mechanical ...[128]

We shall see however, that these classifications in no way reflect the actual development of NEWTON's thought at various levels, and that they are, in part, expedient moves in defense of his position.

VII

In the last two sections the empirical and experimental character of the Definitions of void and body and related documents have been analysed. Quite a different NEWTON is revealed in Section IV. There the character and inter-connections of void space and matter are seen within the context of a theological metaphysics. It must not be supposed that this view is absent from the *Principia*. It is clearly present in the *General Scholium* of the Second Edition. And while in the *Scholium* on space and time, vacuity is not explicitly cited as being one of the attributes of absolute space, nevertheless, it is clearly implied by NEWTON's discussion. To be sure he attempts to secure the existence of absolute space by experimental investigation of rotational motion. Nonetheless, the basic presuppositions of his analysis are still those of the earlier treatises, especially *De Gravitatione* discussed in Section IV.

This leads to a consideration of the following question. Is it necessary to reconcile NEWTON's "operational" statements of the Definitions with the metaphysical and theological approach of the *Scholium*? Especially when the latter presupposes the assumptions discussed in Section IV? The question begins to have point when it is noticed that NEWTON tells us at the end of this *Scholium*

[127] ULC. Add. 3965. 13. Folio 428[r]. On the same sheet is written yet another definition of body. The passage is translated from the Latin.

[128] *Opticks. op. cit.* p. 369.

that he is concerned to show "how we are to obtain the true motions from their causes, effects, and apparent differences and the converse", and that this will "be explained more at large in the following treatise. For to this end it was that I composed it". Now it is the Third Book that deals pre-eminently with the motion[129] of physical bodies: the Definitions, however, make no reference to the absolute character of such motion. Rather, they tend to give the impression that the Third Book is concerned with purely relative motion. Again, the question can be put into relief if we compare the status NEWTON accords to absolute space and motion in the *Scholium*, with what he says of the motions of bodies in an unresisting void in the Definitions. In the *Scholium* we find the following passage: —

> I do not define time, space, place, and motion, as being well known at all. Only I must observe, that the common people conceive those quantities under no other notions but from the relation they bear to sensible objects. And thence arise certain prejudices ...[130]

But in the remarks to the Definitions, NEWTON repeatedly refers to the common people, as a means of suggesting that he is not doing anything like metaphysics in the Third Book, but simply defining the nature of void space and matter in a way which accords with everyday experience. In the context of the controversy with LEIBNIZ, this appeal to the common people is also a way of saying that the Leibnizian criticisms of the doctrine of the void are irrelevant so far as the *Principia* is concerned.

There are a number of factors to be considered in answering this general question. First, in so far as the Third Book is concerned with the movements of gross bodies, the Definitions are not unreasonable as a reply to LEIBNIZ. But as we have seen from the discussion of the corollaries to Proposition VI, the doctrine of void spaces is also held, in part, to characterise the deep substructure of the physical world. It is plain that the Definitions as they stand do not cover the doctrine of the interstitial vacuum. Nor does the Third "Rule of Reasoning", which is concerned with justifying the existence and character of imperceptible particles, but not with the existence of innumerable and actual vacuities in the constitution of matter.[131] Thus even within the framework of the Third Book the Definitions would seem to be unsatisfactory. For with the doctrine of the interstitial vacuum and its implications, NEWTON goes far beyond the world of everyday experience. And the evidence which he adduces for it is not to be found in any of the editions of the *Principia*, but only in suppressed material such as the draft addition to Proposition VI of the Third Book,[132] or in the *Opticks* and their Queries. Moreover, his discussion of such evidence always makes it plain that he thought it did little more than 'illustrate' the existence of these sub-sensible vacuities. Yet the doctrine was essential, as pointed out in Sections I and IV, for his explanation of a large range of phenomena. Thus when faced with LEIBNIZ'S criticisms of his doctrine, and profoundly disliking any sort of controversy, NEW-

[129] CAJORI, *op. cit.* p. 397. The preface to that Book.

[130] *Ibid.* p. 6. The same point is made on p. 11.

[131] I am not suggesting that NEWTON uses the term 'void' in a different *sense* when referring to the interstices of matter; for clearly it is the *same* space that is divided whether by gross bodies or imperceptible particles.

[132] HALL & HALL, *op. cit.* p. 316. *Vide.* Section I.

TON decided to make a minimal claim about the way he was using the terms vacuum and body in the Third Book. 'Other authors' could then dispute about other notions as they pleased. Accordingly, by means of this manoeuvre, he intended to give the impression that nothing more was involved than what the Definitions stated, even though their ostensive 'operational' purpose was out of keeping with the *Scholium* on absolute space and motion.

It is also stated in the remarks to the Definitions that any metaphysical system must be developed in the light of phenomena as understood by experimental philosophy. Since the *Principia* is a technical treatise, is it not the case that with respect to the Definitions NEWTON is justified in discounting the metaphysical and theological setting of his philosophy of nature? However, it is clear from Section IV that his commitment to a metaphysical world view was prior to many of his effective scientific results, and that the refinement of his position and the ability to do science within such a framework developed simultaneously. Indeed it is difficult to see how this could have been otherwise. Thus we must see the assertion that metaphysics comes after experimental philosophy as another polemical move in a bitter controversy.

Again it is clear from the CLARKE-LEIBNIZ *Correspondence* that the Newtonians were finally forced by LEIBNIZ to fight at the most fundamental level. As a result of the work of COHEN & KOYRÉ we are now in a position to say for the first time with certainty, that the philosophy expressed by CLARKE was that of NEWTON himself. Indeed, it is almost certain that one of the reasons why CLARKE was asked to perform this task was the fact that NEWTON did not feel entirely at home with philosophical matters, as is evident from his early treatises. Hence CLARKE performed this philosophical assignment with NEWTON'S continuing approval, defending not only the doctrines of the Queries, but those of the *Principia* as well, by means of philosophical arguments.

In the light of this was LEIBNIZ justified in regarding matter and void as constituting the bare bones of a metaphysical theory? There can be little doubt. It was not merely that there was insufficient experimental evidence for a conclusive demonstration of the theory of level upon level of actual vacuities in matter and its consequent paucity, nor was it entirely the philosophical and theological framework within which NEWTON'S theory of matter was ultimately embedded: more important, perhaps, it was the fact that LEIBNIZ perceived matter and void to be the 'scientific' cutting edge of a systematic way of seeing a very wide range of diverse phenomena. It was not merely a way of seeing empirical facts, but it also involved distinctive religious and moral consequences.[133]

Thus LEIBNIZ saw that Newtonianism embodied the generality, the all-embracing characteristics of a metaphysical system. But for him it was a shallow system for which he had a deep intellectual distaste. As a young man he came to feel 'cramped' in its categories. Now, at the end of his years, he saw this basically ancient way of seeing things becoming ascendant. Fundamentally this is what the *Correspondence* is all about: the serious confrontation of two radically different philosophies concerning the nature of God, man, and the physical world. NEWTON and CLARKE were acutely aware of this fact. The latter did public battle, while the former developed many private arguments, some of which were certainly seen

[133] *Opticks. op. cit.* pp. 405—406.

by CLARKE. It is equally plain from the *Correspondence* and from NEWTON'S deepest thoughts concerning the significance of void space in his system, that should this doctrine be successfully contraverted by the Leibnizians, the whole Newtonian position would be seriously threatened.

Thus we have three facts. In the first place the Definitions are not adequate to justify NEWTON'S appeal to the interstitial void in the Third Book and, connected with this, from a general point of view, they are not in character with the ideas of the *Scholium* on absolute motion in absolute space. Secondly, the Baconian contention that metaphysics, though it has a different subject matter, comes after arguments based on induction, is simply not borne out by NEWTON'S own intellectual development. And lastly, it is clear that he supported CLARKE'S 'philosophical' defence of his own position which is tantamount to admitting, contrary to the views expressed in the remarks concerning the nature of various disciplines, that the arguments formulated in the *Correspondence* are relevant to his experimental philosophy.

We can now consider the initial problem mentioned at the beginning of this section. In the context of these Definitions was NEWTON entirely justified in disregarding the metaphysical and theological orientation of his general philosophy of nature, when the presuppositions underlying this orientation support the *Scholium* on Space and Time, and indeed, certain aspects of Book III? He was certainly entitled to define his terms as he pleased; and in fact he did. But as we have seen, his Definitions did not reflect his total use of the term 'vacuous space' in the *Principia*, and especially in the Third Book. Thus it seems that he was to some extent being disingenuous, by implying that he never meant anything more in his application of the term. Furthermore, it seems that if he had not been formulating these Definitions in defence of his position against LEIBNIZ, he might well have been less prudential in his formulation, allowing himself the liberty of stating or implying the true significance that the doctrine of void space held for him. Since the Definitions were intended to come prior to the Third Book itself, such a liberty would have been in keeping with the policy of the *Scholium* on space and time and the *Generale Scholium*.

The Definitions analysed thus show NEWTON on the defensive, attempting by "experiment" and "commonsense" to bury the true metaphysics of his system in a characteristically Newtonian response to the penetrating criticisms of his Continental rival.

Appendix

Add 3965 sec 17 Draft No. 1 Folio 641

Solida mathematica non sentiuntur tangendo nec resistentiam creant, neque corpora dici solent. ⟨At this point NEWTON has drawn eight lines across the sheet.⟩

Quintessentia ab Elementis quatuor diversa nullis est sensibus obnoxia, nec inter phaenomena numerari potest. Materia prima quae nec quid nec quale nec quantum est non est Phaenomenon. Materia subtiles quae caeli omnes impliantur ⟨a phrase is interpolated here that cannot be made out⟩ non est phaenomenon. Et quae Phaenomena non sunt ea in Philosophia experimentali locum non habent. Argumentum Inductionis ab experimentis *desumptum* & sensibilium observationi-

bus desumptum, in quo Philosophia experimentalis fundatur, ad entia vel hypothetica vel metaphysica quae Phaenomena non sunt, *extendi non debet: applicari non potest nisi per hypothesin:* ideoque quae de corporibus *vi Inductionis* in hoc Libro dicuntur ad ejusmodi entia nil spectant. De solis *Phaenomenis* sensibilibus *et earum partibus* hic agitur *Reliqua* ⟨a phrase is interpolated here that is too heavily scored to be intelligible⟩ *in Metaphysica & Philosophia hypothetica tractanda* ⟨a word is illegible⟩ *sunt* ⟨the following phrase is written above the line⟩ *eo quod Argumentum Inductionis in ÿs solis locum habeat.* Reliqua quae non sentiuntur sed per hypothesin ⟨illegible word crossed out⟩ *tamen a nonnullis* corpora nominantur, in Metaphysica et Philosophia hypothetica rectius tractanda sunt. A phaenomenis incipiendum est. In hic tractandis Philosophia experimentalis consistit. Ab Hac Philosophia ad *causas efficientes & causas Finales* & Philosophiam hypotheticam pergendum est. Orbes solidi in quibus Planetae inhaerant *non sunt Phaenomena.* Materia subtilis & *sine resistentia* ⟨the next word is unclear; but reading 'movent' makes sense⟩ *movent* in qua innatent, non est ⟨NEWTON had first written 'sunt' and then crossed it out⟩ Phaenomenon, *Et quae Phaenomena* ⟨two or three words are unclear⟩ *in hoc fluida sine resistentia.*

Et quemadmodum Geometrae lineam definiunt quae longa est sine latitudine ut *eorum Propositiones* de ejusmodi lineis solummodo intelligantur & *lata tamen linea* in Mechanica *tamen* & alÿs scientÿs *linea lata* locum habeat: sic corpus & *vacuum* hic definiuntur [*non ut alia esse corpora negemus sed ut sequuntur in quo sensu voces accipiantur in sequentibus ostendamus Propositionis quae sequuntur de ejusmodi corporibus hic definitis intelliguntur De alÿs corporibus disputent* Authores in alÿs scientÿs] ut voces in hoc sensu *definito* accipiantur in sequentibus. De alÿs corporibus et alÿs vacuo disputent authores in alÿs scientÿs.

Add 3965. sec 13 (53—94) Draft No. 2 Folio 437v

Definitio I

Corpus voco rem omnen tangibilem qua tangentibus resistitur, et cujus actio ⟨written above the line⟩ *resistentia,* si satis magna sit, sentiri potest.

Hoc enim sensu vulgus vocem corporis semper accipit. Et hujus generis sunt ⟨the word 'Tellus' is heavily crossed out⟩ *Tellus, Planetae, Cometae* metalla, lapides, arena, argilla, lutum, *terra,* salia, ligna, ossa, carnes, aqua, oleum, lac, sanguis, aer, ventus, fumus, exhalatio, flamma, & quicquid sub elementis quatuor comprehendi potest, vel ab his exhalando manare & in haec per condensationem redire: Addo *Tellurem & Corpora caelesia. Haec emittunt & reflectunt* ⟨this phrase is written above the following⟩ *Planetae & Cometae* agunt — Lucem. & *inter* ⟨there are three words here quite illegible⟩ *Phaenomena numerantur* ⟨there is a word written below 'numerantur' which is too heavily scored out to be legible⟩ & *motibus suis observant leges corporum* & a partibus suis incumbentibus premuntur. [Solida mathematica non sentiuntur tangendo, nec resistentiam creant, neque corpora dici solent] Vapores et exhalationes ob raritatem suam amittunt resistentiam prope omnem sensibilem, & apud vulgus saepe amittunt etiam nomen corpora & spiritus vocantur. Corpora tamen vocari possunt quatenus *sunt effluvia Corporum* & resistentiam habent densitati proportionalem [Quod si effluvia corporum ita formis mutarentur ut vim *omnem* resistendi amitterent *et inter Phaeno-*

mena numerari cessarent haec non amplius ⟨an illegible word⟩ vocarem corpora: nam loquor cum vuglo]

Definitio II

Vacuum voco locum omnem in quo corpus sine resistentia movetur.

Sic enim vulgus loqui solet. Siquis contendat corpora dari quae tangendo nec sentiri nec resistentiam creare queant, hic jam disputat ⟨there is an illegible phrase interpolated here⟩ de vocis significatione Grammatica, corpora nominando quae vulgus corpora non vocat: et malim *loqui* cum vulgo *loqui, cujus utique est vis et nomina loquendi.* Quae tangendo (premunt) et premendo agunt in alia, quaeque non premunt & (premendo) non agunt in alia, ita ab invicem distingui possunt; ut (vera)[1] vocentur corpora; altera dicantur res intangibiles, vel res ⟨phrase is missing⟩ *vel materia insensibilium vel* alio nomine designentur; & horum genus commune tertio (nomine) gaudeat, quale est Substantia, vel Ens, vel Agens, vel ⟨there is a phrase missing⟩ Sic enim evitabitur ambiguitas illa verborum ex ⟨a phrase is missing⟩ idearum & contentiones oriri solent. Et cum de corpori ⟨part of the sentence is missing⟩ tanquam Phaenomenis hic disputetur, spatium ⟨part of the sentence is missing⟩ ut Vacuum considero. De natura rerum ⟨part of the sentence is missing⟩ ut Vacuum considero. De natura rerum ⟨rest of sentence is missing⟩ destitutis, disputent par ne licet. ⟨the remaining sentences can not be made out⟩

Add. 3965 sec 13 [53—94] Draft No. 3 Folio 422r

Definitiones

Definitio II

Corpus voco rem omnem *mobilem* & tangibilem qua tangentibus resistitur, & cujus resistentia, si satis magna sit, sentiri potest.

Hoc enim sensu vulgus vocem corporis semper accipit. Et hujus generis sunt metalla, lapides, arena, argilla, lutum, terra, salia, ligna, ossa, carnes, aqua, oleum, lac, sanguis, aer, ventus, fumus, exhalatio, flamma, & quicquid sub elementis quatuor comprehendi potest, vel ab his exhalando manare, & in haec per condensationem redire. Addo corpora caelestia. Haec emittunt et reflectunt lucem et inter phaenomena numerantur, a partibus suis incumbentibus premuntur, figuram rotundam induunt & in motibus suis observant leges corporum. Vapores & exhalationes ob raritatem suam amittunt resistentiam prope omnem sensibilem, & apud vulgus saepe amittunt etiam nomen corporum & spiritus vocantur. Corpora tamen vocari possunt quatenus sunt effluvia corporum & *vim habent* resistentiam *habent* densitati proportionalem. Solida mathematica non *sentiuntur* agunt tangendo *nec resistentiam creant,* neque corpora dici solent. [Quintessentia ab elementis quatuor diversa nullis est sensibus obnoxia nec inter phaenomena numerari potest. Materia prima quae nec quid nec quale nec quantum est, non est phaenomenon. Orbes solidi in quibus Planetae inhaereant non sunt phaenomena. Materia subtilis in qua *Planetae* innatent et *in quibus* corpora sine resistentia moveantur, non est phaenomenon. Et quae phaenomena non sunt nec ullis sensibus obnoxia,

[1] The words in round brackets are conjectural, since the manuscript is torn in the left-hand corner.

ea in Philosophia experimentali locum non habent. Argumentum Inductionis ab experimentis et sensibilium observationibus desumptum, in quo Philosophia experimentalis fundatur, ad entia vel hypothetica vel metaphysica quae phaenomena non sunt, applicari non potest nisi per hypothesin, ideoque quae de corporibus vi Inductionis in hoc libro dicuntur, ad ejusmodi entia nil spectant. De solis sensibilibus et eorum partibus hic agitur propterea quod argumentum Inductionis in ÿs solis locum habeat. Reliqua quae non sentiuntur sed per hypothesin tamen a nonnullis corpora nominantur, in Metaphysica et Philosophia hypothetica rectius tractanda sunt. A Phaenomenis Philosophia incipit *A phaenomenes incipiendum est.* In his tractandis Philosophia experimentalis consistit. Ab Philosophia *experimentali ad rerum ad* causas efficientes & finales, & *ab his omnibus ad naturam rerum insensibilium* & *ultimo* ad Philosophiam hypotheticam transeundum est: Initio Libri primi quantitatem materiae definivi ut tractaretur *physice* mathematice: hic corpus extali materia constans definio ut tractetur physice.

Definitio III

Vacuum voco locum omnem in quo corpora sine resistentia moventur.

Sic enim vulgus loqui solet; et haec vocis significatio ex definitione prima consequitur *Vacuum est quod rebus tangibilibus et contactu sua motum corporum impedientibus vacat.* Quemadmodum vero Geometrae lineam definiunt quae longa est sine latitudine ut eorum Propositiones de ejusmodi lineis solummodo intelliguntur, et in Mechanica tamen et alÿs Scientÿs Linea lata locum habet; sic corpus et vacuum hic definiuntur ut voces in sensu definito accipiantur in sequentibus. De alÿs corporibus et alio vacuo disputent anthores in alÿs scientÿs.

Add 3965 sec 13 [53—94] Draft No. 4 Folio 430r

Scholium

In Definitione prima Libri primi *definitur dixi quid sit* quantitas Materiae in Corpore quovis & me hanc quantitatem per nomine Corporis vel Massae passim intelligere et Medÿ siquod fuerit interstitia partium libere pervadentis hic nullam rationem habere. Et in Definitione tertia *dixi* vim Inertiae corpori insitam proportionalem *insitam* seu essentialem esse et hanc vim esse potentiam resistendi dequa corpus *omne conatur permanere perseverat* in statu suo quiescendi vel movendi uniformiter in directum. Per corpus utique rem omnem intelligo tangibilem *intelligo* qua tangentibus resistitur, et cujus resistentia, si satis magna sit, sentiri potest. Hoc enim sensus volgus vocem corporis semper accipit. Et hujus generis *proptera quod* [et ultimo ad *Philosopiam* hypothesis *Philo* ⟨the word was not completed⟩ transeundum est. Vocem corporis igitur *in hac Propositione* non latus accipio quam in sensu hic definito. Et *vacuum voco* spatium omne hujusmodi corporibus destitutum. Quemadmodum vero Geometrae Lineam definiunt quae longa est sine latitudine, ut eorum Propositiones de hujusmodi lineis solummodo intelligantur; & in Mechanica tamen & alÿs scientÿs Linea lata est: sic corpus et vacuum hic definiuntur ut in sensu definito accipiantur in *hac Propositionem et sequentibus his Libres.* De alÿs Corporibus et alio Vacuo disputent *authores in alÿs scientÿs* alÿ qui extra limites Philosophiae experimentalis vagantur] ⟨There is a large space in the manuscript. NEWTON begins again with a dash⟩ propterea quod argumen-

tum Inductionis in ÿs solis locum habeat. Ideoque quae *hic affirmantur* vi Inductionis de universali corporum gravitate *hic affirmantur*, ad Quintessentias, & Materias primas, et Orbes solidos, et Materias subtiles quae phaenomena non sunt, nil spectant. [Hic loquor de corporibus quae *vere tanguntur* & vere habent *vim* inertiae et per hanc vim tangentibus resistentiam vere inferent] *Ea non sunt corpora de quibus hic agitur* Quae non sentiuntur sed per hypothesin tamen a nonnullis corpora nominantur, in Metaphysica et Philosophia hypothetica rectius tractanda sunt. A phaenomenis *Philosophia* per argumentum Inductionis incipit. In his tractandis Philosophia experimentalis consistit. A philosophia experimentali ad rerum causas *finales et* efficientes, & ab his omnibus ad naturam rerum insensibilium, & ultimo ad Philosophiam hypotheticam transeundum est.

Add 3965 sec 13 [126—149] Draft No. 5 Folio 504r

Definitio I

Corpus voco rem omnem quae moveri et tangi potest et qua tangentibus resistitur.

Hoc sensu vulgus vocem corporis semper accipit. Et hujus generis sunt metalla, lapides, arena, argilla, lutum, terra, salia, ligna, ossa, carnes, aqua, oleum, lac, sanguis, aer, ventus, fumus, exhalatio, flamma, et quicquid sub elementis quatuor comprehendi potest, vel ab his exhalando manare & in haec per condensationem redire. Adde corpora caelestia. Haec *moventur* emittunt et reflectunt lucem & inter phaenomena numerantur; a partibus suis incumbentibus premuntur, figuram rotundam induunt, & in motibus suis observant Leges corporum. Vapores et exhalationes ob raritatem suam amittunt resistentiam prepe omnem sensibilem, et apud vulgus saepe amittunt etiam nomen corporum et spiritus vocantur. Sed sunt spiritus corporei, *et corporei*, et corpora vocari possunt quatenus *sunt* effluvia corporum & vim habent resistendi densitati *suae* proportionalem. Solida mathematica non aqunt tangendo neque corpora dici solent.

Definitio II

Vacuum voco spatium omne per quod corpus sine resistentia movetur.

Sic enim vulgus loqui solet. Et haec vocis significatio ex Definitione prima consequitur. Vacuum est quod rebus tangibilibus et contactu suo motum corporem impedientibus vacat. Quemadmodum vero Geometrae Lineam definiunt quae longa est sine latitudine ut *eorum* de hujusmodi Lineis solummodo intelligantur, et in Mechanica tamen et alÿs Scientÿs Linea lata locum habet: sic Corpus et Vacuum hic definiuntur ut voces in sensu definito accipiantur in sequentibus. De alÿs corporibus et alio vacuo disputent authores alibi.[1]

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[1] Immediately following this on the sheet is the new addition to *Regula* II, the addition to the end of *Regula* III, and *Regula* IV; all of which appeared for the first time in the Third Edition. *Vide* KOYRÉ, *Les Regulae Philosophandi* Note 121.